MEMOIRS

OF THE

NATIONAL MUSEUM OF VICTORIA

MELBOURNE

(World List abbrev. Mem. nat. Mus. Melbourne)

No. 18

Issued May 18, 1953

R. T. M. PESCOTT, M.Agr.Sc., F.R.E.S., M.I.Biol.
DIRECTOR

PUBLISHED BY ORDER OF THE TRUSTEES

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BROWN, PRIOR, ANDERSON PTY. LTD., 430 LITTLE BOURKE ST., MELBOURNE, C.1

NATIONAL MUSEUM OF VICTORIA

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DIRECTOR

R. T. M. PESCOTT, M.Agr.Sc., F.R.E.S., M.I.Biol.

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MEM. NAT. MUS. MELBOURNE, 18, 1953.

THE WILD (FERAL) PIGS OF AUSTRALIA: THEIR ORIGIN, DISTRIBUTION AND ECONOMIC IMPORTANCE

By E. M. Pullar, D.V.Sc.
Veterinary Research Institute, University of Melbourne

Figs. 1, 7; Plates I-III (Figs. 2-6)

INTRODUCTION

Man in the process of colonizing the various land masses of the world has been responsible for deliberately or accidentally introducing many exotic animals into new environments. When these free living or wild animals originate from domestic stock they are frequently referred to as 'feral', although the word 'maroon', of French origin, is occasionally used.

Zoologists seldom give these feral animals the same attention as native fauna, although they may become of considerable importance either as vermin, as a source of economic wealth or through the destruction of native wild life.

Over a period of several years data relating to the Australian feral pigs has been collected primarily to assess their actual or potential role in the spread of infectious disease. Some information of general interest acquired in the course of that investigation is presented in this paper. The subject of the role of feral pigs in the spread of infection is discussed elsewhere.

SOURCES OF INFORMATION

A request for information was made through the press, scientific and farming journals, government departments and to many individuals. Approximately 700 copies of a circular letter (Pullar 1947) were distributed and about the same number of replies received. The number of reports dealing with the various States were:—Queensland 369, New South Wales 99, Victoria 76, Tasmania 5, South Australia 67, Western Australia 43 and Northern Territory 40.

ORIGIN

In many cases local residents were able to give details regarding the origin of the colonies. These were many and varied and included:—(a) the escape of unrestrained domestic stock, (b) accidental escape of domestic stock when farm buildings were wrecked in storms, trucks damaged or overturned in transit or stock travelling on foot were stampeded, (c) deliberate release of farm stock to found a colony or to improve the conformation of existing feral pigs, (d) deliberate introduction of feral pigs to start a colony. All these factors are still operating, and many new colonies have been established in the last 10 - 15 years by

the accidental or deliberate release of domestic stock. On Kangaroo Island a few farmers drove their pigs into the bush about 50 years ago, after a religious revivalist persuaded them that they were unclean animals. These pigs appear to have joined the existing feral colony.

In the case of infested areas near the coast, some local residents were of the opinion that they escaped from wrecked vessels. None could supply other than vague information as to the identity of the craft or the approximate year it went ashore. In every case it was possible to obtain a more probable and well authenticated explanation.

Some of the older existing colonies, viz., the greater part of Queensland and the Northern Territory, Upper Darling and Lachlan-Murrumbidgee Junction (N.S.W.), Flinders Island (Tas.), Kangaroo Island (S.A.) and Darling Ranges (W.A.) originated prior to the memory of the oldest residents (*i.e.* before about 1870). In an attempt to discover their origin a search was made of the available published works of naturalists and travellers. The earliest records of feral pigs which we traced were Finch-Hatton (1885) in Queensland on the Dawson River and Dahl (1926)) on the Adelaide River (N.T.) and near Broome (W.A.) in 1894-6.

The existence of feral pigs in Australia was not generally recognized by naturalists until comparatively recently as the following specifically stated that they did not exist in this country, Afialo (1896), Semon (1899) and Stead (1937).

To ascertain whether feral pigs existed outside the occupied area in the early colonial days the journals of a number of explorers and navigators were studied in detail, selecting those who in the period immediately prior to the expansion of the pastoral industry (1830 to 1865), passed through country now known to be pig infested. The list of journals studied and the routes followed are given in Fig. 1. Although the writers of these journals usually listed the game observed and shot each day and noted the existence of feral cattle, buffalo, dogs, cats, deer and stray horses, only two references to feral pigs were found. Stokes (1837-43) in the *Beagle* saw a few pigs which had been liberated on an island in Bass Strait, and Jukes (1847) in the *Fly* liberated a boar and a sow on an island near the Queensland coast but shot both them and their progeny a year later.

The true explanation of the origin of these colonies appears to lie in the evolution of pig farming in the early days. Some swine were introduced with the first fleet (1788) and others were brought in on many subsequent occasions. At first they were

EXPLORERS & NAVIGATORS		REFERENCE
EYRE 1839-41	—+—+—+—+—	Verbatim account included in Warburton (1875)
FORREST 1869-74	— — — —	Forrest, J (1875).–"Explorations in Australia". Sampson Low, Marston Low and Searle London.
GREGORYS 1846-61	....	Gregory, A.C. and Gregory, F.T (1884).–"Journals of Australian Explorations" J.C. Beal Brisbane.
JARDINES 1864-5	.-x-.-x-.-x-.	Byerley, F.J. (1867).–"Narrative of the Overland Expedition of the Jardine", etc. J.W. Buxton Brisbane
JUKES 1842-6	↙ J	Jukes, J.B. (1847).–"Narrative of the Surveying Voyage of H.M.S. Fly, etc" T.& W. Boone. London.
KENNEDY 1848	xxxxxxxxx	Verbatim accounts included in MacGillivray (1852.)
LANDSBOROUGH 1862	— IIII — IIII —	Landsborough, W (1862).–"Journal of Landsborough's Expedition from Carpentaria in search of Burke and Wills" Wilson & MacKinnon, Melbourne.
LEICHHARDT 1844-5	—II—II—II—	Leichhardt, L. (1847).–"Journal of an Overland Expedition in Australia from Moreton Bay to Port Essington, etc". T.& W. Boone London
MacGILLIVRAY 1846-50	↙ McG	MacGillivray, J. (1852).–"Narrative of the Voyage of H.M.S. Rattlesnake, etc". T.& W. Boone. London.
McKINLAY 1862	—...—...—...	McKinlay, J. (cir. 1862).–"McKinlay's Journal of Exploration in the Interior of Australia, etc." F.F. Bailliere. Melbourne
MITCHELL 1831-6	————	Mitchell, T.L. (1839).–"Three Expeditions into the Exterior of Eastern Australia, etc". T.& W. Boone. London.
STOKES 1837-43	↙ S	Stokes, T.L. (1846).–"Discoveries in Australia during the Voyage of H.M.S. Beagle, etc". T.& W. Boone. London.
STURT 1828-31	-.-.-.-.-	Sturt, C. (1834).–"Two Expeditions into the Interior of Australia, etc". Elder Smith & Co. London.
WARBURTON 1872-4	—x—x—x—x—	Warburton, P.E. (1875).–"Journey across the Western Interior of Australia". Sampson Low, Marston Low, & Searle. London.

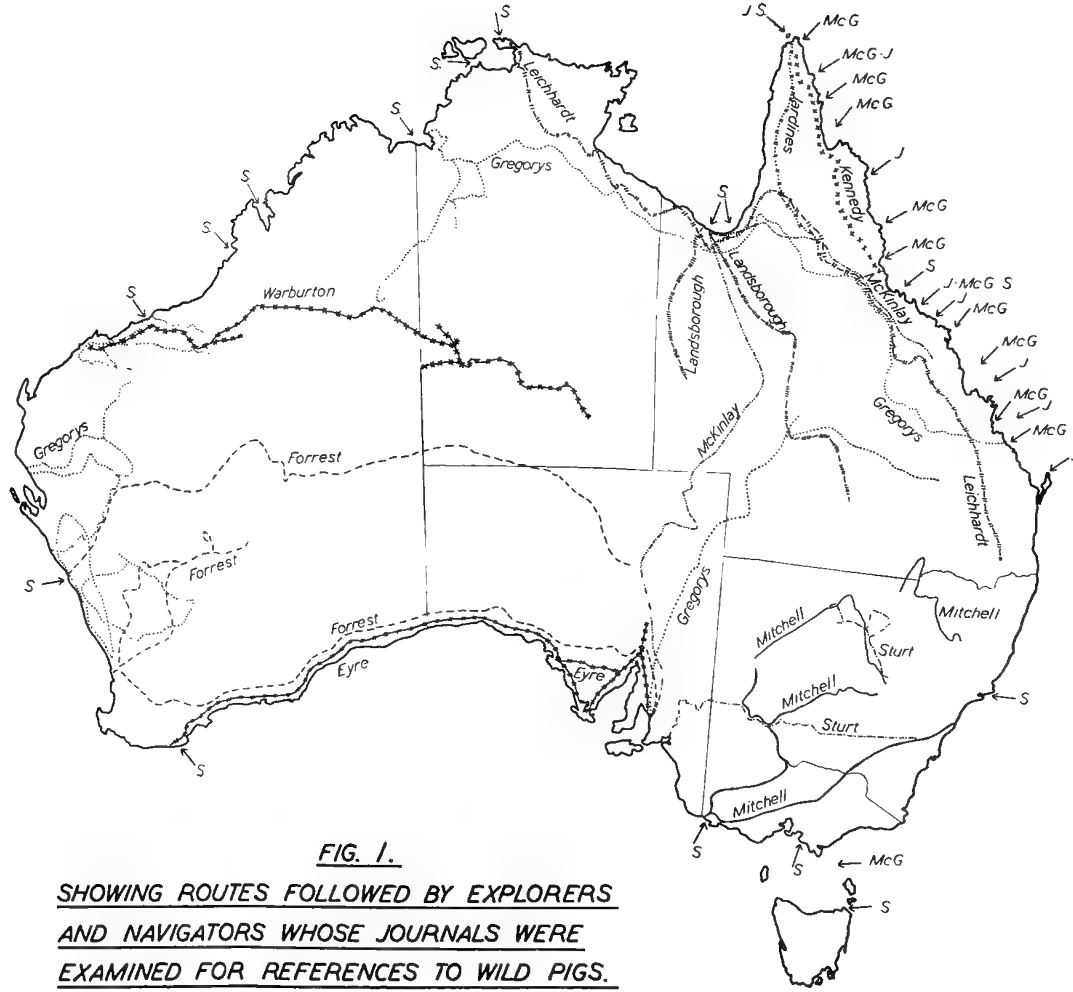

FIG. 1.

SHOWING ROUTES FOLLOWED BY EXPLORERS AND NAVIGATORS WHOSE JOURNALS WERE EXAMINED FOR REFERENCES TO WILD PIGS.

permitted to roam at large around the settlement at Sydney Cove and soon became a nuisance, and as early as 17 February 1795 orders were issued that they could be shot if they trespassed on private property (Robertson 1932). Later a pound system was introduced but they continued to cause trouble for another ten years. They were allowed to run in the bush on an island adjacent to Norfolk Island, but later this project was abandoned as the flesh was unpalatable due to the retention of food flavours. On the mainland, as the occupied area extended pigs were carried into the interior and again allowed to roam at large as the following extracts show:—

> They (pigs) are allowed to run in the bush during the day, just giving each a cob of maize to bring it home in the evening, if not employing a man to look after them. They feed on grasses, herbs, wild roots and native yams, on the margins of rivers or marshy grounds, and also on frogs, lizzards etc. which come their way. (Cunningham 1827.)

> Pigs thrive and breed readily, forming on the whole a valuable stock. They must, however, be allowed to run loose or they will hardly pay. They are, as may be supposed, very troublesome and destructive, and all cultivation must be defended by pig-proof fences . . . . Where there is either a marsh or a brush in the neighbourhood of the station they will generally manage to feed themselves, though a little corn night and morning will keep them in better order and prevent their becoming too wild. (Henderson 1851.)

The latter is of particular interest as it is from a book giving general information for the guidance of farmers and other settlers.

Thus until about the middle of the nineteenth century or shortly afterwards pigs were kept under semiferal conditions in the swamps, marshes and other rough country. After about 1865 when the fencing-in of properties became general and the original runs and stations were subdivided, these pigs would lose their identity as the property of particular owners, and would be left untended to become a pest in later years.

European Wild Boars

European wild pigs were introduced into the Cherokee National Forest, Tennessee, U.S.A., to provide a game animal for hunting (Stegman 1938), and into the Kluitjieskraal plantation in South Africa to control destructive insect larvae (Thomas and Kolbe 1942). We were unable to trace any similar importations into this country.

Asiatic Pigs

For hundreds of years the so-called 'Malays' from Timor and adjacent islands have collected pearls and beche-de-mer from the northern coast of Australia. Although some would carry pigs as

live cargo, they were seldom on friendly terms with the aborigines and would be unlikely to leave any animals behind at their shore stations.

According to the Historical Records of Australia, Series III, Vol. VI, pp. 711 and 841, twenty pigs were brought from Koepang (Timor) to Melville Island in December 1827. A few months later when that settlement was abandoned, all stock (including the pigs) were transferred to Raffel's Bay on the Coburg Peninsula. When the latter settlement was also abandoned shortly afterwards the fattest stock were slaughtered and salted down for the journey to Sydney. The remainder, including sheep, cattle, pigs, fowls and a pair of horses, were driven into the bush. Thus some of the original Timor pigs may have been included amongst those that were liberated.

During the mass immigration of Chinese in the Gold Rush many could have brought pigs with them. In fact, Dahl (1926) writing in 1894-6 refers to the feral pigs of the Northern Territory as Chinese pigs.

We received one unconfirmed report that some pigs were brought to the Daintree River in Queensland from New Guinea before 1900. In addition, Dr. F. H. S. Roberts, of the Division of Entomology of the Commonwealth Scientific and Industrial Research Organization, advised us that he once found *Gnathostoma hispidium* in a feral pig from the York Peninsular. This parasite is common in pigs in New Guinea but has never been seen in domestic pigs in Australia. Both Roberts and Seddon (1947) have suggested this as indicating the illegal entry of 'knackers' pigs.

It is not possible to solve the problem by examining specimens from feral pigs for features characteristic of Asiatic stock as pigs from Siam or some adjacent country were imported into England between 1750 and 1800 and used to improve the Berkshire, Middle White and possibly other breeds (Lynch 1914, Robinson 1922, and Peirson & Owtran 1945). As both these breeds were very popular in Australia their feral descendants could easily carry these characteristics.

Bass Strait Sealers

Early in the nineteenth century the islands in and near Bass Strait were occupied by a semi-nomadic, polyglot collection of escaped convicts, half-castes and a few free men. These were referred to collectively as 'Sealers' or 'Straitsmen'. They lived by collecting young sea birds, feathers, eggs, fish, seal skins, blubber, etc. They moved from island to island following available

supplies. Jukes (1847) and others noted that they had put pigs, dogs, rabbits and other stock on various islands to breed at will, thus providing a useful addition to the food supply. The existing colonies on French and Kangaroo Islands no doubt originated in this way. The use of old place names such as Hog Bay (Kangaroo Island) is usually taken as an indication that feral pigs have been located there for a considerable time (Hallack 1905 and Martin 1943).

THE CAPTAIN COOK HYPOTHESIS

It is commonly held, particularly in Northern Queensland, that Captain Cook introduced pigs into Australia and in consequence feral pigs are sometimes termed 'Captain Cookers'. The liberation is supposed to have been made at the Endeavour River (near Cooktown) where Cook careened his barque for repairs.

We could not find any evidence to support this hypothesis which is probably a confused version of the deliberate liberations in New Zealand.

An examination of the following copies of Cook's Journal and Log: (a) as edited by Synge (1897); (b) transcribed by Bonwick (1886); and reprinted together with those of several other members of the crew of the Endeavour in The Historical Records of N.S.W., Vol. I, Part I, 1893, provided the following facts which indicate that Cook did not liberate pigs on the mainland of Australia.

1. After Cook had completed his observations of the Transit of Venus he reprovisioned at Tahiti and then sailed west discovering and surveying the coasts of New Zealand and Australia. The provisions from Tahiti included a number of live pigs, but the majority died from exposure before reaching New Zealand and very few were still alive when the *Endeavour* was in Australian waters.
2. No pigs were liberated in New Zealand during the First Voyage. The introductions were made during the Second and Third Voyages.
3. Cook careened his ship at the Endeavour River to repair the damage caused by striking a coral reef six days before. Although this was successful it was found that the pumps were almost useless. Cook was therefore caught in the narrow waters between the Barrier Reef and the mainland, with no knowledge of the location of the few passages to the coral sea or of the route to the nearest known settlement (Java), and dependent on his own supplies and the soundness of his ship for an indefinite period. It is considered

highly improbable that he would discard such valuable cargo as live pigs under such circumstances.

4. The aborigines were at first tolerant but later openly hostile to the white visitors, and towards the end of their stay fired the grass around their camp on two occasions. This was in marked contrast to the usually friendly and tolerant attitude of the Maoris.

Describing one of these fires, Cook stated:—

> Luckily at this time we had hardly anything ashore besides the forge and a sow with a litter of young pigs, one of which was scorched to death in the fire. (Synge 1897.)

It is considered unlikely that pigs would be deliberately released under these circumstances and that he would have mentioned any accidental escape.

5. Although the presence of pigs on a number of islands of the South Pacific was noted in the account of the First Voyage, the first mention of the intention to release them in New Zealand occurs early in the account of the Second Voyage. This suggests that the decision was made in England between the two Voyages.
6. During the Second Voyage, sheep, pigs and geese were bought at Capetown with the deliberate intention of liberating them in New Zealand. Unfortunately the majority of these died before reaching that country, and the few survivors were showing signs of malnutrition. These and others obtained from Tahiti were liberated at several points in New Zealand. Cook did not revisit Australia during the Second Voyage.
7. On the Third Voyage, Cook obtained further pigs from Capetown. Although these were liberated chiefly in New Zealand, two were set free at Adventure Bay on the Island of Bruni near Tasmania, which Cook thought was part of the mainland of Australia. Cook had difficulty in restraining the aborigines from killing them, and had no doubt as to their ultimate fate.

He does not mention any previous liberations in Australia, and as this was his only contact with this country after his First Voyage there were no other opportunities for introductions.

Association of Pigs with Aborigines

Although it is generally agreed that there is no evidence of aborigine-pig association, no great reliance can be placed on negative evidence. More definite information was supplied by J. W. Chapman, of the Edward River Mission, Queensland, who

Fig. 2
A young, sty-reared, 'Recent Type' feral sow, captured near the Lachlan-Murrumbidgee junction, N.S.W. Note the well-developed mane.

Fig. 3
An 'Early Type' feral boar, shot near Albatross Bay, Cape York, Queensland.
Photograph by *D. L. Belcher, Weipa Mission, North Queensland.*

FIG. 4
A mature feral sow from the Macquarie Marshes, N.S.W.
Photograph by *Sgt. H. P. Orman, Moree, N.S.W.*

FIG. 5
A mature, sty-reared, 'Recent Type' feral sow captured near the Lachlan Murrumbidgee junction and used for breeding baconers.
Photograph by *F. J. Thompson, Manangatang, Vic.*

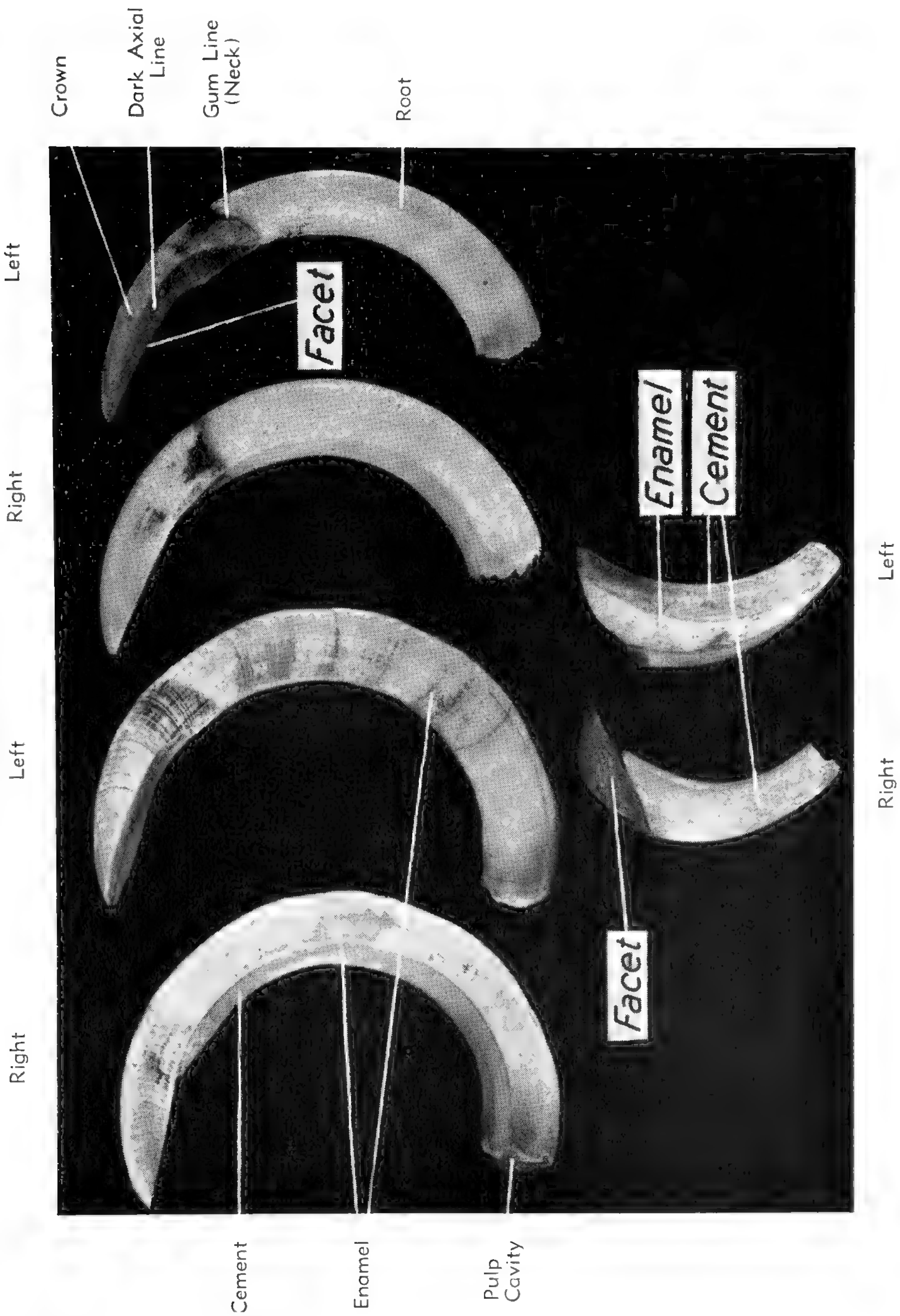

FIG. 6

Tusks from feral boars.

informed us that there is no aboriginal word for pig, and that the natives use the English term 'pig' or some modification such as 'piggy-pig'. This fact was investigated by the staff of the National Museum, Melbourne, who reported that no aboriginal word for pig is listed in any of the vocabularies in their possession.

Appearance

The feral pigs are extremely variable in their appearance although in some areas local types are recognized by the presence of some characteristic colour, marking or other feature.

In general the feral pigs (Figs. 2 to 5) resemble poor type domestic pigs but are lean and muscular with narrow backs, usually referred to as 'slab-sided' or 'razor-backed'. The predominant colour is described as black or black and white, but this includes rusty or reddish blacks and blue-blacks. Other colours are reds, fawns, duns, roans, white and mixed colours. Occasionally agouti coloured animals are seen but they are comparatively rare. White saddles, spots and tiger markings have been noted in a few districts. In some localities whole colonies of white pigs have been observed.

The majority of pigs have large heads with long snouts although short snouted animals are sometimes seen.

The shoulders and neck, particularly in the boars, are well developed. This appears chiefly to be due to the exercise of rooting, as the shoulders and necks of sty-reared feral pigs are not very large.

In some animals there is a mane of long erect bristles extending along the mid-dorsal line for a variable distance from the head (Fig. 2).

Old boars usually have well developed keratinous plaques or shields on their shoulders. The horny layer in this region may be $\frac{3}{4}$ in. (2 cm. thick).

There are two extreme types of feral pigs which may conveniently be designated the 'Early Type' and the 'Recent Type'. There is, however, a large and varied range of intermediate forms. The early type pigs appear to becoming increasing scarce, and the recent type the predominant animal.

The early type pig is described as small, black or dark red in colour, with a large head and shoulders, narrow back and very small hind legs. The sows would not weigh more than about 70 lb. and the boars about double that weight (Fig. 3).

The recent type pig resembles a poorly developed modern domestic pig. These are relatively larger, the sows being up to

about 150 lb. and the boars up to 300 lb. or even more. They are commonly black or dark red, but a high proportion are of lighter or mixed colours. White pigs are sometimes observed. The head and shoulders are large and well developed, the back is broader and the disproportion between the fore and hind legs less marked (Figs. 4 and 5.)

It is considered that the pigs of the early type are the direct descendants of those which escaped or were liberated early in the settlement of the continent (70 to 120 years ago), while the recent type pigs are the progeny of recent additions.

Juvenile Striping.

Dorsal longitudinal stripes in shades of brown and fawn are sometimes seen in the suckers, but they disappear as they grow older.

Unfortunately this subject was not specifically included in the list of questions asked, although it is now realized that it might provide information regarding the possible introduction of Pacific Island pigs into this country. Dorsal stripes in the young are rarely seen in the domestic breeds in this country, although it is the normal colour in New Guinea and the adjacent islands.

Some observers volunteered the information that they had noted stripes in the young local pigs. All but two of these reports referred to the area between Cooktown and Cairns (North Queensland). The two exceptions were of a general nature and did not apply to any particular district.

Tusks (Fig. 6)

The canine teeth or tusks of the male are large, well developed, and project out of the mouth and act as formidable weapons of offence.

The lower canines are 150-300 mm. (5-12 inches) long, triangular in cross-section with sides 16-25 mm. ($\frac{5}{8}$-1 inch) wide. They are curved upward, outward and backward, forming an arc of a circle slightly less than 60 mm. ($2\frac{3}{8}$ inches) in diameter. The lesser curvature is covered with yellowish cement and the other two with creamy-white enamel. All surfaces are marked by longitudinal and transverse ridges. Approximately four-fifths of the tooth is embedded in the lower jaw. The canine teeth grow continuously during life as they have permanent pulp cavities.

The upper canines are considerably shorter, being about 90 mm. ($3\frac{1}{2}$ inches) long and 25 mm. (1 inch) wide. They are approximately oblong in cross section, and curve outward and backward

in a horizontal plane. The greater curvature is covered with enamel, and the remaining surfaces with cement.

The function of the upper canines is to act as whetstones to the lower teeth, keeping them sharp and worn down to the correct length. By this means the lower tusks are provided with pointed, razor-sharp facets 35-70 mm. ($1\frac{1}{2}$-$2\frac{3}{4}$ inches long).

If an upper canine is accidentally or deliberately removed, the corresponding lower one will continue to grow in a complete circle, ultimately re-entering the mandible. According to Troughton (1943) the natives of New Guinea sometimes deliberately remove the upper canines to produce these overdeveloped teeth for bangles. On the mainland, tusks are frequently collected and polished for ornamental purposes.

During the course of this investigation a number of polished and natural tusks were made available for detailed examination. These consisted of 23 pairs of lower canines and a pair of upper canines. Seventeen lower pairs and the single upper pair were collected in Queensland by Mr. E. J. Shelton, of the Queensland Department of Agriculture and Stock. One pair of lower canines was collected from Southern New South Wales by Mr. A. Murdoch of Melbourne, and the remaining four by Mr. K. C. Edwards from Kangaroo Island.

The only reasonably constant dimension was the radius of the greater curvature of the lower tusks. In the series of 23 pairs examined the range was 48 to 64 mm., the mean 57·5 mm. and the standard error ± 1·2. There was so little variation in this measurement that it may be of value in the classification of the genus *Sus*. Unfortunately this possibility cannot be explored as very little suitable material is available in Australia.

Geographical Distribution

(Fig. 7)

The position is far from static, as the pigs continually infiltrate into new suitable areas, and at the same time are slowly being eliminated by the advance of closer settlement. For this reason, the present distribution can only be described in general terms.

The pigs are not evenly scattered throughout the infested areas, but are located in colonies on water courses, in swamps, and in rough and heavily timbered country. In the north-eastern part of the continent, the colonies are regarded as contiguous, as they lie mainly within the normal wandering range (10-20 miles) or along natural lines for expansion, such as permanent or occasional water-courses, coastal swamps, etc.

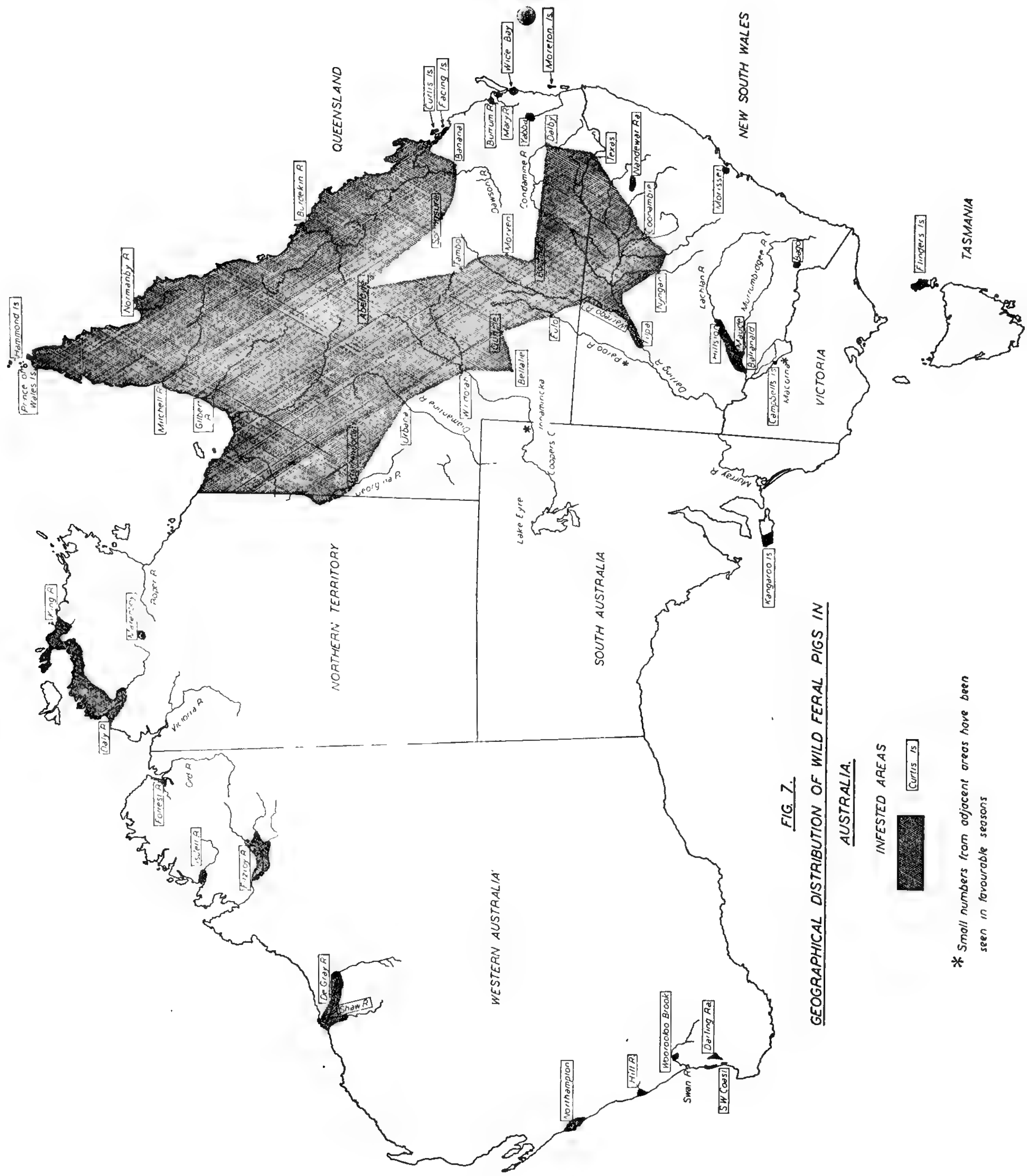

FIG. 7.

GEOGRAPHICAL DISTRIBUTION OF WILD FERAL PIGS IN AUSTRALIA.

Some difficulty was experienced in collating the reports as a number of observers referred to former colonies as though they still existed, although they admitted that they had not seen them for years.

In general, the present distribution is:—

Queensland

The pig infested area covers the greater part of the State except the low rainfall region to the south-west, the closely settled portion in the south-east and the relatively treeless Mitchell grass plains on the western slopes of the coastal ranges. Isolated colonies occur near the coast on the Burrum River, Mary River, Wide Bay area and Brisbane River (near Yabba). Colonies are also found on the following islands: Prince of Wales, Hammond, Curtis, Facing and Moreton.

New South Wales

The pig infested area extends from Queensland into New South Wales. This includes the Darling River to as far south as Tilpa and its tributaries from the Warrego to the Bogan. In favourable seasons pigs may be found on the Paroo, having followed the flood water down from Queensland.

In addition, isolated colonies are located in the swamps around the Lachlan-Murrumbidgee junction, the Nandewar Ranges, Campbell's Island (on the Murray River near Barham), Morisset (near Newcastle) and Bago (in the State Forest near Tumbarumba).

Victoria

There has been a number of colonies of feral pigs in Victoria, but the last one, which was located on the headwaters of the Gellibrand River in the Otway Forest, was destroyed by the bush fires of 1938-39.

In favourable seasons a few wandering pigs, probably from the colony near Barham, have been seen as far south as Macorna.

Tasmania

There is a colony on Flinders Island, but feral pigs do not appear to have become established on the main island.

South Australia

The only existing colony is located on the western end of Kangaroo Island.

Western Australia

There is a number of isolated colonies which are located around the mouth of the Forrest River and the coastal marshes to the north, the mouth of the Isdel River, the upper reaches of the Fitzroy River, the DeGrey River and its tributary the Shaw River, the coast near Northhampton, the mouth of the Hill River, the Wooroloo Brook (near the Avon River), the Darling Ranges in the south-west, and part of the adjacent coastal swamps.

Northern Territory

The records are incomplete, as large areas are uninhabited or set aside as Aboriginal Reserves. Known existing colonies are located on the coast and rivers of Eastern Arnhem Land and the Coburg Peninsula from the King River to the Daly River, and the swamps near Maranboy.

Damage and Economic Loss Due to Pigs

Feral pigs are responsible for considerable economic loss by destroying stacks of fodder, vegetable, cereal and sugar cane crops, breaching vermin-proof fences, fouling water holes and rooting up tracks, embankments of tanks and drains.

They destroy enormous numbers of small terrestrial animals and by eating the eggs have almost exterminated ground nesting birds in some areas.

It is generally held that pigs kill large numbers of new-born domestic animals, particularly lambs, and that they will attack weak stock trapped in mud-holes during dry spells. The position is not absolutely clear as reliable observers expressed some doubt regarding pigs killing such large animals.

It is well established that they eat carrion, but it has been noted both here and in New Zealand (Mackintosh 1941) that they frequently leave carcases until they have ripened for a few days. They have been seen eating foetal membranes from lambing ewes. On the other hand, none of our informants stated that they had ever seen a pig kill a live lamb or other domestic animal.

Alternative explanations which should be considered are: (1) the pigs eat the lambs and other new-born animals immediately they are dropped and before they begin making active movements, or (2) as with the Norwegian rat (*Rattus norvegicus*) which is supposed to kill chickens and ducklings, only a small number of the older and larger individuals become predatory, and the whole species is blamed for their depredations. One report supported

this view by stating that if the older boars and sows are killed off there is very little trouble with lambing ewes.

Value and Exploitation

Feral pigs have a definite economic value. They are highly regarded as an alternative source of meat in sheep and cattle country. In fact, many station owners allow a few to remain on their properties for that purpose. Others deliberately release well-bred boars to improve the feral stock.

In and near pig country a number of farmers depend on the feral pigs for replenishing their stock for fattening. Some even cross them with well-bred boars (Fig. 5).

Pigs kill and eat large numbers of small and medium sized snakes, and in some districts have been responsible for their virtual extinction. Pigs are not naturally immune to snake-bite, but depend on a tough, resistant skin, a thick layer of subcutaneous fat and, like the mongoose, on relatively quicker muscular movements (Henry 1934).

Feral pigs by destroying carrion also play an important role in blowfly control. In fact some farmers encourage their presence for that reason.

Bionomics

Habits

Feral pigs are mainly nocturnal, hiding under cover, preferably near water, during the day and appearing in the open late in the afternoon.

They appear to be gregarious, as the colonies include both sexes and all ages, although they usually forage singly or in small groups.

They generally avoid human contact, but old males become very savage and have been known to attack dismounted men without provocation and have run under horses and disembowelled them with a slash of their tusks.

Diet

Pigs are omnivorous and their diet is extremely varied, in fact they consume anything edible that is within their reach. Under natural conditions the diet includes leaves, fruits and roots of edible plants, grubs, beetles, shellfish and other small animals.

Carrion appears to form a large part of their diet, and decaying carcases are soon demolished in pig infested country. After a fire the pigs move in to devour the dead birds and animals. Where trapping operations are in progress the pigs follow up the lines, eating the skinned carcases and even taking the game from the traps.

Habitat

Feral pigs are found in all types of country including coastal sand dunes, marshes and mangrove swamps, open and dense forest, scrub and savannah lands, inland swamps, rivers and occasional water-courses, rough mountains and open plains. In all localities the animals have three requirements—water, an assured food supply, and cover in which to hide during the day.

Movement

Although they tend to remain near their usual habitat, their daily foraging range is up to 5 or 10 miles. Odd animals (usually mature boars) have been noted up to 20 miles from the nearest known colony.

There is some evidence of seasonal movement, particularly in those localities where they are restricted to the vicinity of permanent waterholes during the dry season. The advent of the wet season or periodical floods enable them to range over a much larger area.

They also tend to concentrate in areas where food is plentiful, following the ripening of natural crops of tubers and fruits and the chance accumulation of carrion during droughts or after bush fires.

Nests

Information on this subject is very scanty. It appears that under certain conditions they build large, well-camouflaged nests up to six or eight feet in diameter. These structures consist of interlaced branches, fern fronds and grass. It has been suggested that they are mainly constructed by sows to hide and protect their litters. Reports of nest building were received from western and southern Queensland, northern New South Wales, Kangaroo Island, and the Darling Ranges (in Western Australia).

Nest building by *Sus scrofa* and other pigs has been noted in other parts of the world.

Control

Natural Enemies

The most important natural enemy of the feral pig is white man, and several isolated colonies have been wiped out entirely by human agency.

According to a nunmber of reports the aborigines did not kill many pigs until about 1900, but they now eat large numbers and in some districts have also exterminated them.

There are few predatory animals in Australia which can kill an adult pig. The only native marsupials large enough to attack small or medium sized animals are the Tasmanian Wolf (*Thylacinus cynocephalus*) and the Tasmanian Devil (*Sarcophilus harrisii*), neither of which is found in pig infested country.

In the tropics the crocodile (*Crocodilus porosus*) and the python (*Python amethystinus*) are important natural enemies, but their geographical distribution is restricted.

The wedge-tailed eagle (*Uroaëtus audax*), dingo (*Canis dingo*), fox (*Vulpes vulpes*) and the feral dog kill numbers of suckers, but are too small to successfully attack adult pigs.

Other Means

Apart from accidental or natural phenomena such as bush fires or floods, control has largely been by hunting and poisoning. In the past it was left to individual effort, at times stimulated by the payment of bonuses or 'scalp money' by property owners, public companies (such as sugar mills) and municipalities. Records of the payment of bonuses go back at least as far as 1870.

Recently in Queensland the payment of a standard bonus of two shillings has been organized over a large area, including almost all that part west of the coastal range. Since pigs were gazetted as 'vermin' under "The Stock Routes and Rural Lands Protection Acts" on the 7th July 1945 the annual number destroyed has varied between 23,496 and 34,512, which is equal to approximately twenty *per cent* of the total number of domestic pigs slaughtered in the whole State.

The results so far appear to be very satisfactory, but it is too soon to assess them accurately.

Acknowledgments

The author wishes to thank the following for their assistance in this survey:

The many private individuals and officers of government departments who supplied the data on which this survey is largely based; the editors of the newspapers, magazines and scientific journals who published the request for information; the people who supplied the photographs of wild pigs; Mr. K. C. Edwards of Kangaroo Island, Mr. A. Murdoch of Melbourne, and Mr. E. J. Shelton of the Queensland Department of Agriculture and Stock who made available the tusks for detailed examination; Mr. F. J. Thompson of Manangatang (Vic.) for presenting a young wild boar for observation (this boar was later transferred to the Zoological Gardens, Melbourne); Miss M. E. Cocks of this Institute for her assistance in preparing the maps and collating the data on geographical distribution; and the Queensland Land Administration Board for supplying the data relating to the number of bonuses paid for the destruction of pigs in that State.

Summary

1. The wild pigs of Australia originated from escaped domestic stock and should therefore be termed feral pigs.

2. There is no evidence that pigs existed in Australia prior to its occupation by white men.

3. In the early colonial days pigs were kept under semi-feral conditions in swamps, marshes, etc., or were liberated on coastal islands.

4. There is no evidence of the deliberate introduction of European Wild Boars.

5. Some Asiatic pigs may have been introduced prior to and during the Gold Rush, and there is some evidence of the importation of pigs from New Guinea into North Queensland.

6. From the available information it appears highly improbable that Captain Cook liberated pigs in Australia.

7. The appearance of the feral pigs varies considerably, but in general they are small, narrow-bodied and rough with big heads and shoulders and small hindquarters. A large proportion of the pigs are black, although other colours are seen.

8. The radius of the greater curvature of the lower canines is remarkably constant (mean $57 \cdot 5 \pm 1 \cdot 2$ mm.) and may be of some value for the classification of the genus *Sus*.

9. A large part of Queensland and northern New South Wales is infested with pigs. Isolated colonies are also present in Queensland, New South Wales and Western Australia, and on a number of coastal islands including Kangaroo and Flinders Islands.

10. Feral pigs do considerable damage to crops, fencing, water-works and drains, stacked fodder, native fauna, etc. They also kill large numbers of lambs.

11. Feral pigs have some economic value in that they provide a useful alternative source of meat in sheep and cattle country, and are used as a source of store stock by some farmers. They are important scavengers of carrion, and thus indirectly reduce the blowfly population.

12. Habits, diet, habitat and range of movement are briefly described.

13. Control has been attempted by hunting, poisoning and the payment of bonuses for their destruction.

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GEOLOGICAL EVIDENCE IN WESTERN VICTORIA RELATIVE TO THE ANTIQUITY OF THE AUSTRALIAN ABORIGINES

By Edmund D. Gill, B.A., B.D.
Palaeontologist, National Museum of Victoria

Plates I - IV

Summary

Three periods of aboriginal occupation of the Lake Colongulac area are known, viz.: (1) Time of the extinct giant marsupials, before the local ash vulcanism, as shown by fossil dingo and a carved bone. The age is thought to be late Pleistocene. (2) The mid-Holocene arid period, as shown by a fossil aborigine in a loess dune. (3) The very recent period.

At Pejark Marsh a millstone proves the presence of aborigines as a contemporary of the extinct marsupials and before the local ash vulcanism. The age is believed to be late Pleistocene or early Holocene.

At Bushfield, an axe, bones, and other circumstantial evidence shows the aborigines were present when the Tower Hill volcano first became active, which is thought to be not very much more than 1,000 years ago.

Two series of aboriginal kitchen middens of different ages are described.

Introduction

Three sites in the Western District of Victoria have been reported as significant in a study of the antiquity of man, viz:

1. Lake Colongulac, near Camperdown.
2. Pejark Marsh, near Terang.
3. Bushfield, near Warrnambool.

Geological work in this part of Victoria has thrown some light on the age of the sites, and so each of the above will be discussed in order below. Middens for which radiocarbon age determinations have been made are reported.

1. Lake Colongulac

The general geology of the area has been studied as far as needed to fix geological age, and a detailed examination made of the site at Lake Colongulac. For previous work on the area see Grayson and Mahony (1910).

Bullenmerri Calcareous Clay

The bedrock of the area is a marine calcareous clay, highly fossiliferous. It is yellow where it outcrops round the crater lakes, but blue or bluish-grey when met at depth in bores. The

yellow colour seems to be due to oxidation of the fossil land surface it represents. The best exposure of this rock is round Lake Bullenmerri, and so the formational name *Bullenmerri Calcareous Clay* is proposed. Kennon (1885), Tate and Dennant (1893, p. 215), Searle (1912), and Chapman and Crespin (1935, p. 123) refer to the fossil content of this rock. In the National Museum of Victoria (Cudmore Collection) there are fossils labelled "Wirigils, N.E. Camperdown. Rock samples of limestone and clay, probably from a boring or sinking". The specimens show that the Bullenmerri Calcareous Clay was met under the volcanics of Mt. Wiridgil. Mr. J. C. Jehu, boring contractor, of Camperdown, informs me that only once has he been successful in piercing the blue clay, and that was with a bore sunk on the property "Puunyart", 7 miles N.W. of Camperdown, in the homestead paddock near the tennis court about 100 yards north of the house. The log of bore 1* shows:

Black clay and buckshot	4 ft.
Grey clay	8 ft.
Yellow drift sand	3 ft.
Pure white pipeclay	20 ft.
Yellow clay and salt water	43 ft.
Blue marine clay and shells	100 ft.
Black coarse sand, and shell fragments ..	4 ft.
Total depth bored	182 ft.

Mr. Jehu obliged me with a sample of the sand from the bottom of the bore, and it was found to contain a few polyzoa and numerous foraminifera. The latter were sent to Mr. A. C. Collins, who reported on them (slide N.M.V.† P15546) as follows:

I have found no evidence in the form of restricted species to place it definitely, but on the general assemblage it appears to me to be Balcombian, having some likeness to the Orphanage Hill and Western Beach beds. Species suggesting this relationship are—

Liebusella rudis (Costa) recorded from Orphanage Hill, Western Beach, Balcombe Bay, and Altona Bay coal shaft.

Gaudryina collinsi (Cushman) recorded from Western Beach.

Triloculina sp. A large heavy triloculine with a ring-shaped tooth in the aperture, probably undescribed. Common at Western Beach and Orphanage Hill.

Dorothia sp. A large smooth form, which seems to be undescribed (not *parri*). Occurs at Orphanage Hill.

*For ease of reference, bores and excavations mentioned in this paper are numbered serially, and shown on the maps by these numbers.

†N.M.V. = National Museum of Victoria registered number.
P. = Palaeontological collection.

Gnotuk Basalt

Over the eroded surface of the Bullenmerri Calcareous Clay was poured a number of basalt flows which Grayson and Mahony (1910) have termed the earlier basalts, to distinguish them from the later flows associated with the ash and scoria. The two basalt suites are readily distinguished both physiographically and lithologically. The former are widespread, weathered, eroded, generally compact, and tend to be coarse-grained, while the latter are restricted flows, very fresh, commonly vesicular, fine-grained, but often full of blebs or bigger masses of olivine. As far as is known, no ash was associated with the earlier vulcanism, whereas fragmental ejectamenta characterize the latter, the lava flows being subsidiary. There is thus a big difference in the gas/lava ratios of the two vulcanisms, the former being effusive and the second essentially explosive. These flows are part of the great basalt plain of Western Victoria, which covers some 9,000 square miles, and reputed to be the third largest in the world. Mahony and Grayson (1910) gave an account of the petrology of these rocks. Recently, Dr. A. B. Edwards determined the rock on the S.W. side of Lake Bullenmerri for Mr. A. N. Carter as crinanite (analcite-olivine-dolerite).

Evidence for there being a number of flows is provided by bores on the "Chocolyn" estate, on the east side of Lake Colongulac, the logs of which were kindly made available by Mr. P. Law Smith. They are bore 2 on the south side of the homestead, and bores 3 and 4 on the west and east sides respectively of a dam on a small creek ¾ mile E.N.E. of the homestead. The creek has no name, but is called Windmill Creek in this paper.

Rock	Bore 2	Bore 3	Bore 4
Surface soil	3 ft.	9 ft.	2 ft.
Black clay	8 ft.	12 ft.	15 ft.
Very stiff yellow clay (loess)	11 ft.	4 ft.	15 ft.
Black basalt	37 ft.	15 ft.	10 ft.
Red gravel	3 ft.	2 ft.	4 ft.
Blue clay	3 ft.		
Blue basalt	5 ft.		
Red gravel	2 ft.		
Black basalt	1 ft.		
Total depth bored	73 ft.	42 ft.	46 ft.

The top of bore 2 is 36 ft. above the extra high 1951 winter level of the lake (hereinafter referred to as H.W.M.), while bores 3

and 4 are 22 ft. above the same level. Analyses of the water by Avery and Anderson are as shown below.

Substance	Bore 2	Bores 3 & 4
Ca	11·1	5·3
Mg	8·0	8·0
Na	27·3	24·9
K	2·9	
HCO_3	63·4	63·4
Cl	48·7	31·3
SO_3	1·9	2·0
NO_3	0·75	Trace

Grayson and Mahony (1910, p. 14) record a well (excavation 22 in text-figure 1) between Lake Gnotuk and Lake Colongulac having three basalt flows separated by decomposed rock and covered by 15 ft. tuff, making a total depth of 70 ft. The inter-basaltic deposits indicate not inconsiderable erosion intervals between the flows. These three basalts could be the same three flows as met with in the "Chocolyn" bores. However, it is not easy to define the extent of the earlier basalt flows nor to describe the nature of their terrain, for this is now covered by a blanket of tuff and other deposits.

What is apparently a point of eruption was noticed south of the Mt. Leura caldera (see text-figure 1). In a quarry (excavation 1) on the north side of the road there were counted some thirty pieces of country rock in the basalt. They were pinkish-yellow, fine-grained, non-calcareous sandstones baked by the lava. Two specimens were selected, viz. (a) a piece showing signs of stratification, and containing somewhat greenish angular inclusions of a similar rock. The structures were reminiscent of those seen in some Jurassic strata in Victoria; and (b) a finer grained homogeneous specimen with some basalt attached. These samples were kindly examined by Dr. A. W. Beasley, the Mineralogist of the National Museum of Victoria, who reported that they have a similar mineral composition, consisting chiefly of felspar, quartz, and mica, with the felspar/quartz ratio about three to one. The rocks are therefore felspathic sandstones or arkoses, and undoubtedly come from the underlying Jurassic strata. That they should be so numerous, and only altered in colour, suggests that the Jurassic rocks are not at a very great depth. Skeats and James (1937, p. 247) report that "Among the ejectamenta included in the scoria beds of Glen Alvie, near Red Rock, are fragments of plant-bearing, freshwater, Jurassic felspathic sandstones, and of marine Cainozoic sediments". Alongside Excavation 1 is the highest point at which the basalt occurs in this area. As the ground slopes

FIG. 1

Geological Map of the Camperdown District based on Grayson and Mahony (1910), but modified where field observations provided new information. Aerial photographs were also used for Lake Colongulac and the area south of it. The lake levels shown are low summer levels. The numbers prefixed by B are bore sites, and those prefixed by E are excavation sites as detailed in the text.

in the direction of Lake Colongulac, it is quite possible that the basalt there came from this eruption centre.

The earlier basalt outcrops round the south rim of the Mt. Leura caldera, where it is covered by something like 40 ft. of tuff; it also outcrops strongly round the rims of the crater lakes Bullenmerri and Gnotuk. For this formation the name *Gnotuk Basalt* is proposed. The basalt forms cliffs about 12 ft. high on the west and north shores of Lake Colongulac; it outcrops also on the east shores from under the loess, forming headlands. Only one small outcrop was noted on the south shore, where older rocks are mantled with tuff. However, it outcrops strongly ¾ mile further south towards Camperdown, and this seems to have been the shore of the pre-tuff lake.

A bore put down at the sanitary depot (bore 5) at the south end of the lake went through a few feet of black soil, some tuff, and then to 62 ft. in yellow clay, finishing in drift sand. The top of this bore is about 20 ft. above the winter level of the lake. A windmill bore (no. 6) on the west side of Lake Colongulac proved:

Black soil	6 ft.
Tuff	55 ft.
Red buckshot	4 ft.

Bore 7 for a windmill in the same area proved:

Soil	5 ft. - 6 ft.
Basalt	60 ft.

Bore 8 nearby proved soil and tuff to a depth of 21 ft. The bores thus indicate that the basalt does not now at any rate form a continuous cover, and its surface was diversified before being covered by the ash spread.

Two Types of Lakes

In the area under discussion there are two types of lakes (*cf.* Grayson and Mahony, 1910) viz.:

1. Deep, roundish, crater lakes.
2. Shallow, irregularly-shaped, consequent lakes.

The levels of the former are a function of the water-table, while the levels of the latter are a function of surface accumulation. Lake Colongulac and the associated Lake Kariah belong to the second type, while the nearby lakes Bullenmerri, Gnotuk, Keilambete, and Purrumbete belong to the first type. Lake Colongulac has an area of 3,500 acres, Kariah 350, Bullenmerri 1,330, Gnotuk 600, Keilambete 770, and Purrumbete 1,450 (Hall, 1912).

There has been considerable confusion over the name of Lake Colongulac. Dr. Hobson, in a letter dated 1846, said the aborigines

called the lake "Colungoolac". In pioneers' letters dated 1853 (see Bride 1898), only the name Lake Timboon is given. In 1855 Adeney (see Owen 1877, pp. 184-185) gave the name as Timboon or Colungulac, stating that the aboriginal name was Golongulac. In the same year Bonwick referred to it as Timboon or Corungulac. The same author in 1858 called it Colongulac or Timboon. Etheridge (1878, p. 194) and Johnston (1888, p. 312) refer to Lake Columgoolac. Dawson (1881) gave the native name as Kuurnkolak, and its meaning as "small sand". Wall (1888) spelt it Colangulac. In 1903 Gregory gave the name variously as Kolongulac (pp. 124, 126) and Colongulac (p. 125 map). Hall (1912) in the official Year-Book spelt the name Colongulac and gave the alternative name Timboon. In all publications of later date noted, the name is invariably Colongulac, and there is seldom reference to the older name of Timboon. When the area was first settled, there was a village called Timboon on Timboon Creek near the lake, which was also called Timboon. In 1851, Surveyor R. D. Scott laid out the present town of Camperdown, and wisely put it on higher ground. The village of Timboon gradually disappeared, but confusion has been caused by the fact that a much more recent township about 20 miles to the south has been given the old name of Timboon. Lake Colongulac thus has had two names, and for the present name at least nine spellings have appeared in print. Lake Timboon and Lake Colongulac have been quoted as separate localities for the giant extinct marsupials, but they are one and the same place. (See Plate 1, figures 1 and 2.)

Chocolyn Silts

Overlying the Gnotuk Basalt at Lake Colongulac is a series of clayey silts of lacustrine origin. The Lake Colongulac area was originally a sheep station called "Chocolyn", and the original homestead with a smaller holding still occupies the S.E. side of the lake. This is taken as the formational name of the silts. The type locality selected is the shallow quarry on the present "Chocolyn" estate south of Windmill Creek and just south of a basalt headland (see text-figure 1). From this quarry a collection of the bones of extinct giant marsupials was made by Mr. Law Smith senr., and presented to the National Museum in 1923-24. A spade excavation continued by an auger hole (excavation 2) proved the following succession:

Top	8 in.	grey silt and superficial deposits
	11 in.	reddish gravel rock with *Coxiella confusa* Smith*

*Miss H. Macpherson, Conchologist, of the National Museum of Victoria, says, "The nomenclature of the genus *Coxiella* appears to be in a very confused state, but the above shell is that described by A. E. Smith as *C. confusa*.

2 in. grey silt
6 in. reddish gravel rock with *Coxiella;* at the base is a *Coxiella* band
28 in. grey silt at top, then yellow underneath.
Bottom Basalt at 4 ft. 7 in.

Coxiella is indicative of brackish water conditions, but it has a wide range of tolerance, being found both in comparatively fresh lakes like Lake Bullenmerri and in very salty waters. The silt beds are clayey but contain a considerable amount of fine quartz and other minerals. The grey and yellow silts are compact, and the reddish gravel rock tough, Mr. Law Smith using explosive to quarry it.

The relationship of the Chocolyn Silts to the loess is shown by an auger hole (Excavation 3) on the edge of the loess cliff immediately behind the quarry, the top of the hole being 16 ft. above H.W.M.

9 in. black soil hillwash
4 ft. 1 in. yellow loess
3 ft. 7 in. red gravel in brownish clay
1 ft. 9 in. solid red gravel rock
Basalt chipped at 10 ft. 2 in.

The red gravel in clay may be an old soil horizon. The loess was powdery although bored in mid-winter. The boring contractor who put down the "Chocolyn" bores referred to the loess as "very sticky yellow clay" probably because he puddled water into it with percussion tools. The above auger hole shows that the basalt underneath rises away from the lake, while the grey and yellow silts thin out. The red gravel rock is not very extensive, being only a couple of chains in extent laterally. There is another deposit of similar size, also on the south side of a basalt headland, near the "Chocolyn" homestead. Grayson and Mahony (1910) mark this as "bone bed", but Mr. Law Smith found no fossils there when he quarried it. Both the above localities for red gravel are in protecting arcs of basalt. The presence of little red pebbles of this material in conglomerate at the S.E. corner of the lake suggests that this rock once had a wider extent.

The red gravel rock is a most unusual type of sediment. It consists of roundish pebbles from about 1-16th inch to 1½ inches in diameter, but usually ⅛ inch to ¼ inch. Roughly half of them are of the same rather light grey of the silt stratum underneath, while the rest are brick-red in colour, giving the rock its general reddish appearance. In the fresh rock there do not appear to be any intermediate stages—either the pebbles are grey or they

are red. The pebbles are of silt, and they have been secondarily cemented so as to constitute quite a hard, or rather tough, rock. Dr. A. W. Beasley and the author examined some of the pebbles and found they contained a small percentage of heavy minerals, mostly rounded, from both granitic and basaltic sources; the light fraction includes a good deal of quartz and somewhat decomposed felspar and biotite.

The best section of grey silt observed was in a spade excavation (no. 4) and auger hole put down in a creeklet about 100 yards west of the Rifle Range at the south end of the lake, and two chains from the lake cliff. The following succession was proved:

3 ft. 6 in. black soil (alluvium)
3 ft. horizontally stratified tuff (base of tuff 9 ft. 2 in. above H.W.M.)
5 ft. 2 in. light-grey compact silt (not penetrated)

At the northerly tip of the flats (former lake bed) round the headland on the south shore of the lake a spade excavation (no. 5) showed:

12 in. grey silt
3 in. red ironstone sand and gravel
9 in. yellow clayey silt (not penetrated)

On the west side of the same flats a similar succession was found (Excavation 6):

8 in. grey silt
2 in. dark-yellow iron concretions and red ironstone sand
6 in. yellow silt (not penetrated)

Numerous spade excavations showed that the grey silt is always over the yellow silt. In Excavations 5 and 6 ferruginous deposits intervene, and this is due to a large bed of massed buckshot gravel* mostly lithified to an ironstone which occupies the lake bed on the east side of the headland. Tools available could not pierce the ironstone, but its geological relationships suggest that it lies on the yellow silt.

The Pre-Tuff Lake

The Chocolyn Silts have been traced by a series of spade and auger holes round the lakeside from Excavation 2 to where they pass under the tuff at the south end of the lake. At the S.E. corner of the lake, about 200 yards north of the windmill at the sanitary depot, two spade excavations proved the silts under the tuff which in turn was under the loess.

*The term used in Victoria for what elsewhere is called ironstone gravel or pedalferric nodules.

Excavation 7 (on former lake floor not far from cliff):

6 in. soil
8 in. horizontally bedded tuff *in situ*
8 in. grey silt (not penetrated)

Excavation 8 (at base of cliff):

1 ft. 4 in. soil and loess
3 in. tuff
8 in. grey silt with some brownish patches (not penetrated).

On the south shore near the foot of the cliff in the sanitary depot Excavation 9 showed:

1 ft. 6 in. tuff
6 in. pebbles
6 in. grey silt (not penetrated).

Excavation 4 and a section in Timboon Creek (Excavation 10) both showed the grey silt under the tuff. Over this distance, which is about half a mile, the grey silt is horizontol, being overlain by horizontally-bedded tuff except along the lake cliff where a former high level has undercut the tuff, causing the collapse of large blocks.

The volcanic ash fell into a lake more extensive than the present one, for the tuff (i.e. lithified ash) in the creek sections lies directly on horizontal lacustrine silt with no soil layer intervening. At Excavation 4, a fine carbonaceous layer was noted between the silt and the tuff; in it were poorly preserved plant remains that suggested water weeds. In the bottom layers of the tuff were found small fragments of shells, some of which were clearly from lamellibranchs. A fragment showing a piece of hingeline was shown to Miss Hope Macpherson, Conchologist of the National Museum of Victoria, who stated that it is almost certainly *Corbicula*. In the salt and brackish water lakes of the Western District, *Coxiella* is the only shell found so far (*cf.* Shepard 1918), no lamellibranchs being present apparently. *Corbicula* is common, but always in fresh water, especially moving water as in rivers and creeks.

The pebbles found in Excavation 9 were of calcareous concretions mostly, but some were of tuff. They were mixed with rounded grains of milky quartz, clear quartz, rose quartz, fresh olivine, limonite, iron ore, and fragments of ?*Corbicula*. The lake was brackish at the time the Chocolyn Silts were laid down, as shown

by the presence of *Coxiella,* and it is suggested that this deeper water at the S.E. end of the lake led to where a creek entered. That the water was deeper is shown by the fact that for a short distance at the sanitary depot, the tuff occurs about 10 ft. lower than its usual level. To interpret all the above facts as a creek entry would account for the *Corbicula,* their invariably fragmented condition, the pebbles (including tuff ones), and the coarse sand (including fresh olivine). The creek probably drained the slopes of the basalt flows from the vent referred to on page 28, for the town of Camperdown lies in an open valley of basalt partly filled with tuff.

The pre-tuff lake was more than 10 ft. deeper than the present lake at its highest level in living memory (H.W.M.), local residents claiming the 1951 level to be the highest for over 30 years. The pre-tuff lake reached further south, but in the west had much the same boundary, being confined by the basalt. On the east it spread to the basalt shown in bores 2-4, but ran a considerable distance up the creek beds. To the north the pre-tuff lake extended for a considerable distance, coalescing with the present Lake Kariah and small lakes still further north. Also the lake floor has had an ash spread thrown over it in addition to erosion products, so that the pre-tuff lake basin would be deeper than the present one, even though some sediment was blown away during the arid period. The whole geologic process is towards the elimination of lakes by filling their basins with sediments. The climate at the time of the ash vulcanism must therefore have been much more pluvial than the present one in order to fill a deeper and much more extensive basin, and at the same time to deposit silts to a level some ten feet higher than the highest experienced level of water. Consequent lakes like Lake Colongulac have a vast surface area relative to their volume, and so a rise of over ten feet in level represents a big change in conditions. Constant renewal is necessary if the level is to be maintained because of the extensive evaporation surface.

In times of drought Lake Colongulac dries up completely in midsummer, and the floor glistens with a layer of salt. From records kept by Mr. Law Smith senr., it was ascertained that during the past 30 years, the lake went dry in twelve summers, viz., 1923, 1927-1931, 1933, 1935, 1938, 1940-41, 1945. Other factors besides evaporation can affect the drying of the lake. For example, it dries very rapidly when the wind keeps reversing. The water then blows up and down the lake floor, being spread over extensive areas of dry surface, which quickly absorb a considerable quantity. The lake has not dried up during the years 1946-1951.

Extinct Giant Marsupials

Lake Colongulac is the classic locality in Victoria for the extinct marsupial fauna. From thence came the first fossils of that fauna from Victoria; they were described by Professor Sir Richard Owen of the Royal College of Surgeons, London, and among them was the holotype of *Thylacoleo carnifex* (Owen 1859). The fauna recorded is as follows:

Animal	Literature Reference
Diprotodon optatum Owen	McCoy 1876, Keble 1945
Thylacoleo carnifex Owen	Owen 1859
Procoptodon goliah Owen	McCoy 1879, De Vis and Hall 1899
?Palorchestes ("The Colongulac Bone")	Spencer and Walcott 1911 Keble 1947
Macropus titan Owen	McCoy 1879
M. magister De Vis	De Vis and Hall 1899
M. pan De Vis	*Ibid.*
Thylacinus rostralis De Vis	De Vis and Hall 1899
Canis familiaris dingo Blumenbach	McCoy 1882
Doubtful	
Vombatus pliocenus (McCoy)	McCoy 1879
Macropus canguru (Müller)	De Vis and Hall 1899

The *Diprotodon* is that usually called *D. australis,* but as Simpson (1930) has pointed out, Owen overlooked his own earlier name for this species. It should be noted that De Vis says the jaw of the thylacine is larger than the type. The presence of *Vombatus pliocenus* is questioned because no specimen has been found in any of the collections from the Chocolyn Silts. McCoy (1879, p. 10) records, "Specimens (of *Procoptodon goliah*) figured are from the Pliocene Tertiary clays of Lake Timboon, on the shores of which they are cast up after storms, with various species of *Macropus,* the *Phascolomys pliocenus* McCoy, and the *Thylacoleo carnifex* Owen." *Vombatus* does occur with the extinct marsupial fauna, but that it occurs with this fauna in the Chocolyn Silts has yet to be proved. The specimens of *V. pliocenus* figured by McCoy in his *Prodromus* from the Camperdown District are from Lake Bullenmerri and Holocene in age (uppermost Pleistocene at earliest). One of the specimens is red and mineralized (N.M.V. P7441) while the other (P7442) is whitish and unmineralized. However, mineralization is not necessarily an indication of antiquity. The writer found on the shores of Lake Bullenmerri a red and mineralized leg bone of a cow which was almost exactly twice the weight of a similar unmineralized one. As the district has been occupied by white people for only a little over a century, the mineralization has taken place in that time. As the first

settlers were sheep farmers, the bone is probably well under 100 years old.

Macropus canguru is also placed on the doubtful list. Morrison-Scott and Sawyer (1950) have shown that "Captain Cook's Kangaroo" is the Great Grey Kangaroo, which is therefore not to be called *M. giganteus* Shaw or *M. major* Shaw, but *M. canguru* (Müller) 1776. De Vis says that the specimen of *M. canguru* he examined from Lake Colongulac was not mineralized, so may not belong to the old fauna, but was a surface bone picked up with the others at the time. In Law Smith's collection, there are two comparatively whitish and less mineralized jaws of *M. canguru* (one with soil attached) that either belong to a later period, or have been leached at or near the surface.*

Many collections have been made from Lake Colongulac in the past hundred years, but they have all been picked up loose on the beach, the bed from which they came being unknown. In order to establish the antiquity of man at this site, it is necessary to know

(a) from which bed or beds the fossils came, and
(b) the age of the bed or beds.

The writer has been able to determine the former, and estimate the latter. The first white people to live in the Camperdown district were the brothers Manifold, who settled on the banks of Lake Purrumbete in 1839. In 1843 the area about Lake Colongulac was taken over by a settler named William Adeney. In January 1846, Dr. Henry Hobson of Melbourne wrote to Professor Owen, stating, "I send . . . . a box which contains some interesting fossil bones, from a lake 80 miles S.W. of Melbourne. They were discovered and kindly forwarded to me by Mr. W. Adeney, who has a sheep station on the banks of the lake. I have since visited the lake, which is called by the aborigines *Colungoolac*. . . . The fragment of skull and incisor I hope may be new to you." In August 1855, Adeney himself wrote to Owen, describing the occurrence of the bones. He said, "On the beach in 1843 when I first arrived *disjecta membra* overspread many yards of the surface. . . . I have given away hundreds of these specimens." The fossils were thus numerous but *non in situ*. Hall likewise records (1899, p. 108), "The bones, accompanied by concretionary nodules of calcareous matter, lie loose on the lake beach almost due north of the township, and appear to have come from a clay bed which occurs about water level. As the banks of the lake are

*Since this paper was written, the determination of fluorine/phosphate ratios suggests that *Macropus canguru* did belong to the ancient fauna.

low, it is not easy to say from the evidence there displayed whether the bone bed or the tuff is the older, though my impression has long been that the clay was the underlying deposit. I have recently been informed that in well-sinking not far from the lake margin, bones were obtained in a clay bed which was reached after sinking through the sandstone." "Sandstone" is the local name for the tuff. Pieces of conglomerate with the light-grey calcareous nodules have been found by the writer with pieces of bone in them. The conglomerate also has fragments of shell and red silt pebbles as found in Excavation 2. The conglomerate occurs only at the S.E. corner of the lake where a pre-tuff creek used to enter. The clay bed Hall referred to is the Chocolyn Silt which has been traced by excavations and auger holes, and it definitely underlies the tuff. Grayson and Mahony (1910) were inclined to the opinion that the bones came from the tuff itself, while Keble (1945) listed the bone-bed above the tuff. Chapman (1930) thought the bones might be old cave deposits. In the National Museum of Victoria there are two collections of extinct marsupial bones presented in 1923 and 1924 by Mr. and Mrs. Law Smith senr., who at that time and until recently occupied "Chocolyn". Mr. Law Smith kindly showed me where these bones came from, and I collected some fragments myself. They were blasted from the red gravel bed of the Chocolyn Silts at Excavation 2. The unusual matrix of the quarry is to be seen on many specimens in the Museum. On examining the other collections in the Museum from Lake Colongulac (those of Dr. T. S. Hall, Mr. G. Sweet, Mr. A. D. Hardy, Dr. G. B. Pritchard, and others) it was found that many of the fossils had matrix attached that proved they came from either the red gravel, the conglomerate of the S.E. corner, or the grey clayey silt, *i.e.* they all came from the Chocolyn Silts formation. None possessed a matrix of either tuff or loess—the only other rock types in the area from which they could possibly have come.

Bonwick (1855, p. 26) says the type of *Thylacoleo carnifex* came from the eastern side of the lake.

Preservation of the Fossils

The bones from the Chocolyn Silts are heavy because highly mineralized, are red in colour, and when fresh the surfaces are shiny. A few have been bleached either in part or wholly through exposure on the shore of the lake. As basalt underlies the Chocolyn Silts, the only other formations from which the bones could come are the Hampden Tuff and the Colongulac Loess, but as stated, the bones did not come from them. No bones have been found in

the tuff, but some have come from the loess, and contrast with those found in the silts. They are generally slightly leached in that porous matrix, unmineralized, and light instead of heavy. They are yellow and not red, and their surfaces dull and not shiny.

Another important feature about the bones from Law Smith's quarry, and from the conglomerate at the S.E. corner of the lake, is that they are remanié. Inside the bones is a fine light-grey silt, such as forms the lowest member of the Chocolyn Silts, but which contrasts with the gravel or conglomerate on the outside. Dr. A. W. Beasley kindly made a petrological examination of the matrix infilling the bones presented by Mr. Law Smith. The light minerals present are quartz, decomposed felspar, and a little mica. The heavy minerals (slide E535) in order of abundance are black iron ore, pyroxene (mainly augite, but also enstatite and hypersthene), zircon, garnet, olivine, rutile, and tourmaline. The iron ore (probably ilmenite) and pyroxene grains are generally large, little rounded, and poorly sorted. Their detrital history has not been long, and they with the olivine have come from the underlying basalt. The zircon, rutile, and tourmaline grains are smaller and much more abraded. They come from granitic rocks known to underlie some of the area, and their detrital history has been much longer. The grey silt matrix on a bone in the Hall collection of Lake Colongulac fossils was examined and found to have a closely similar mineralogical composition (slide E536). A sample of grey Chocolyn Silt from the auger hole at Excavation 4, at a depth of five feet below the tuff, proved also to be indistinguishable mineralogically (slide E537) from the matrix infilling the bones from Law Smith's quarry. On the other hand, the mineral composition of the overlying loess contrasts with that of the silt in that the percentage of basaltic minerals is greatly increased. This is to be expected in view of the fact that an ash spread took place between the deposition of the Chocolyn Silts and the building of the loess dunes.

The grey silt is in a condition of chemical reduction, turning light brown on ignition. The red mineralized bones, being in a condition of chemical oxidation, could not have reached their present condition in this silt, and so must have been in a different environment before coming where they were found. The larger bones are little affected by transport and cannot have come far, but the small pieces of bone are well worn, apparently due to being washed up and down the beach. It appears that the bones were mineralized (perhaps in an old terrace), then washed into the grey silt, and then into the gravel or conglomerate. This involves two levels of the lake much higher than any experienced since

European occupation of the area, and two cycles of erosion and deposition.

Extinct and Extant Faunas

The extinct fauna found in the Chocolyn Silts is found at a number of sites in the lake district of Western Victoria. McCoy in his *Prodromus* records many giant forms from Lake Colac. Grayson and Mahony (1910) found similar fossils at Blind Creek, while Keble (1947) found *Diprotodon* under the tuff at Pejark Marsh where Spencer and Walcott (1911) had found *Palorchestes* cf. *azael* and *Macropus* cf. *titan*. Keble (1945) records *Nototherium* from Watch Hill on the N.E. shore of Lake Corangamite between Beeac and Cressy, but had some doubt concerning the locality because of confusion over the name of the place. That Keble's explanation of the site is probably correct is shown by the following letter found recently in the Museum:

Berry Bank,
Cressy.
September 1872.

Professor McCoy,

Enclosed I send you some bones that were found in lime stones when sinking a well, about twenty-two feet deep, on Messrs. Bell and Armstrong's property at Watch Hill.

As we cannot make out what sort of animal they belong to, if possible will you be kind enough to let me know what they are, and you will much oblige,

Yours truly,
(Signed) Joseph Mack.

The mineralized bones with the letter are *Vombatus*. The same gentleman sent from the same place in 1906 a mineralized calcaneum of a large kangaroo. Thus the Watch Hill people found fossil bones, were in touch with the National Museum, and may well have sent the bones referred to by Keble. A giant kangaroo jaw was found at Ondit, east of Lake Corangamite.

Giant marsupial jaws in a silty matrix are in the National Museum "from Hon. Neil Black's station". Mr. Neil Black was one of the original settlers of the area round Mt. Noorat. In July 1951, Mr. John Manifold of "Purrumbete", near Camperdown, presented to the Museum a large collection of fossils including many extinct marsupials such as *Diprotodon, Thylacoleo,* giant *Macropus,* and a jaw of *Sarcophilus* larger than the extant species. Mr. Manifold had no record of the locality from which these bones came, but a study of the matrix showed that it is not probable that they came from Lake Colongulac. For instance, pieces of volcanic cinders are attached to some of the specimens,

and ejectamenta as coarse as that have not been seen by me at Lake Colongulac. In the National Museum there are some giant marsupial bones presented by Mr. W. T. Manifold (father of Mr. John Manifold) which appear to be a selection from the same collection. In 1916 Mr. W. T. Manifold presented a fossil jaw of the *Macropus titan* type, which was labelled "Purrumbete, Victoria". One could assume that this is the locality from which they came, but it could be only the donor's address. Thus the locality for the collection is unknown, but it could be Lake Purrumbete. Along with the extinct marsupial bones were also lightly mineralized bones of different preservation belonging to extant forms, bones of aborigines, and aboriginal implements; some of these bones and implements are known definitely to have been found on the property, and this increases the possibility of the whole collection coming from there. The extinct fauna is a pre-tuff one, because the matrix is a fine silt similar to the Chocolyn Silt, but in some cases with little pebbles of cinders attached after the bones were washed out of the original bed.

In 1933, during sewerage excavations in the city of Warrnambool, a cave was opened in Pleistocene aeolianite on the south side of Skene Street, between Banyan and Kelp Streets, ten feet from the surface. A number of bones, unmineralized to mineralized, were obtained from Mr. J. Jukes, and were determined at the time by Mr. C. W. Brazenor, Mammalogist, National Museum of Victoria, as

Procoptodon sp.
Macropus cf. *anak* Owen
Vombatus mitchelli (Owen)
Thylacoleo carnifex Owen
Aepyprymnus rufescens (Gray)

in addition to other kangaroo, wallaby, bird, sheep and rabbit remains. Extinct marsupial bones are also known from Hawkesdale, north of Warrnambool.

The extinct giant marsupial fauna is thus quite widespread round the area under discussion, and not limited to Lake Colongulac. Where the age of the giant forms can be determined, as at Lake Colongulac and Pejark Marsh, they are Pleistocene, and earlier than the local ash vulcanism.

In striking contrast with the extinct fauna is the post-tuff fauna which consists entirely of living species. At Lake Colongulac, all the forms definitely from the Chocolyn Silts are extinct except for the dingo. On the other hand, quite numerous vertebrate fossils have been collected from the terraces of the crater lakes

nearby, but none of them belong to extinct species. Typical is the fauna from Lake Keilambete, which includes

Macropus canguru (Müller)	Great grey kangaroo
Wallabia	Wallaby
Vombatus cf. *mitchelli* (Owen)	Wombat
Potorous tridactylus (Kerr)	Dark rat-kangaroo
Cygnus atratus (Latham)	Black Swan

Similar faunas have been collected from Lakes Gnotuk and Bullenmerri. McCoy (1882) recorded *Sarcophilus ursinus* from a cave in the tuff at Lake Purrumbete, and *Dasyurus viverrinus* has been found in the tuff at Terang.

Although there is this marked break between pre-tuff and post-tuff faunas, there is no evidence to suggest that the volcanic eruptions were responsible for the extinction of the former in this area. The bones found under the tuff at Lake Colongulac are remanié, and so do not belong to the time immediately before the eruption. Nevertheless the blanketing of vast areas with a layer of volcanic ash must have had considerable biological repercussions, and although no connection between the disappearance of the giant marsupials and the eruptions can be demonstrated, it is certain that when the area was re-populated, only living species were present to effect this. Even though the vulcanism itself may have occupied a comparatively short period of time, probably quite a considerable break is represented between the extinct and extant faunas as found fossil in the Lake Colongulac area. As far as present evidence goes, the extinct fauna is Pleistocene, and the extant fauna Holocene. The passing of the pluvial period prior to the mid-Holocene "Thermal Maximum" (when the loess dunes were built) is taken as the end of the Pleistocene.

Hampden Tuff

This formational name was given by Grayson and Mahony (1910) to finely-bedded tuffs that cover much of the Camperdown and contiguous districts. This very wide use of a formational name is scarcely in keeping with the definition since established (Glaessner *et al.* 1948). Each distinguishable ash spread is a separate lithological unit, and to merge them can be confusing. The Terang Tuff, Keilambete Tuff, and Purrumbete Tuff are such separate units, and hereby proposed as formations; the respective lake bank sections provide the obvious type localities. At Mt. Leura there is a yellow tuff readily distinguishable from the earlier slate-grey tuff of the initial cone, and it is herein separated from the Hampden Tuff and included in the Leura

Volcanics. Referring to the Hampden Tuff, Grayson and Mahony (1910, p. 6) say, "The best sections are seen in the cuttings along the road which crosses the neck of land between Lakes Bullenmerri and Gnotuk . . ." This first-named site may be taken as the type locality of the Hampden Tuff.

An average rainfall of 29·11 inches falls on the Hampden Tuff each year (Hounam 1949); the State average is 24·27 inches (Aird 1945). This small rainfall is fairly well distributed over the year (the lowest monthly fall is February 1·45 inches, and the highest is August 3·41 inches), and the tuff is highly absorbent. The result is that no permanent streams flow over it. Further west is the Mt. Emu Creek which in spite of being 165 miles long (15 miles longer than the River Yarra) never becomes a large stream. A strongly incised physiography is therefore not to be expected in the tuffs, but there are other evidences of considerable weathering. The soils are deep and there is a well-developed layer of buckshot gravel. For example, on the flat ground near Excavation 4, a spade and auger hole proved (Excavation 15):

2 ft. 6 in.	heavy, black, alluvial soil
2 in.	large buckshot nodules in soil
11 in.	decomposed tuff (ground increasingly tuffaceous)
	solid tuff at 3 ft. 7 in.

Excavations in connection with the reservoir at the top of the hill on the Camperdown-Cobden road, two miles S.W. of Camperdown, show the plentiful development of buckshot in the soil on the tuff (cf. Grayson and Mahony 1910, p. 9). However, the nodules are not as numerous as in the pre-basaltic soil profiles, which are laterized.

Another notable weathering feature is the presence of soil pipes. Plate 4, figure 8, shows these in the south wall of Excavation 13 near Mt. Leura. The dark chocolate soil, which is 2 ft. 6 in. deep, extends down into pipes which are a further 4 ft. 6in., the bottom of the longest pipe being thus 7 ft. from ground level. The pipe narrows from 23 in. diameter at 4 ft. from the bottom to 9 in. diameter three inches from the bottom. The pipes figured are in reddish-brown to blackish volcanic cinders, but are seen also in the yellow tuff exposed in the same quarry and in the quarry on the opposite side of the road (Excavation 14). They are not so deep as in the cinders, which may be due to the rock being much less porous. Dr. Tomlinson (1941) has described in England a brown loam with ironstone nodules which extends into underlying gravels as pipes. The stratification of the gravels is

apparently quite unaffected by the process of pipe-formation (Plate XXI, fig. 2). Such pipes appear to be the product of percolating waters in a time of plentiful rainfall.

Support for this explanation is provided by the fact that soil pipes are not found on the very steep slopes. For instance, in the quarry at the foot of the steep cinder cone of Mt. Leura (Excavation 14), pipes are absent from the steep side of the quarry, but numerous where the slope eases off into flatter ground. Also the pipes tend to be associated with hollows in the terrain. They appear to be homologues of the solution pipes found in the Pleistocene aeolianite. These are vertical tubes of travertine which are no longer in use as natural drains, and usually filled with fossil soil (cf. solution pipes in English chalk—Burnaby 1950). The soil pipes are thus surely solution channels, but it should be noted that where they occur on the cinders and agglomeratic yellow tuff at Mt. Leura (Excavations 13 and 14), and on cinders at Mt. Noorat (large quarry on west side), they are associated with unleached and immature, though deep, soils. These soils are dark brown to chocolate loams 2 ft. 6 in. to 3 in. thick, but without a profile developed in them. The soils on the Leura Volcanics are quite immature, while those on the surrounding grey tuffs are well-developed podsols. Professor G. W. Leeper, of the University of Melbourne, kindly examined a series of fossil and extant soils for the writer, and described the soil seen on tuff in the excavation for the reservoir 1½ miles S.W. of Camperdown (Excavation 23) at a mature podsol with a grey silt-loam A horizon, and a red-yellow-grey mottled clay with buckshot gravel as a B horizon. At present it is not understood whether the immaturity of the soils on the Leura Volcanics is due to younger age, or difference in pedogenic process from that on the Hampden Tuff.

The Hampden Tuff contrasts with the Tower Hill Tuff which has a shallow soil, and no buckshot gravel layer. There are no soil pipes in the latter, although there are soil pipes associated with the soil on which it lies. The Hampden Tuff was ejected a considerable time before the mid-Holocene arid period as represented by the loess dunes resting on its eroded surface. On the other hand, the Tower Hill Tuff was subsequent to mid-Holocene clay and limestone on an emerged late Pleistocene marine shell-bed to be seen on the Moyne River near Tower Hill (pp. 74-76). At Camperdown the extant marsupial fauna is always found on top of the tuff, while in the Warrnambool district it is found under the tuff as well as over it. The Hampden Tuff is thus older than the Tower Hill Tuff.

The Volcanoes

In attempting to determine the age of the Chocolyn Silts and their contained fossils, it is important to know when the volcanoes were active and for how long. It is possible that small quantities of volcanic ash reached Lake Colongulac from afar, but the five or six feet of finely-bedded horizontal tuff seen at the south end of the lake must have been derived from one or more of the three volcanoes nearby, viz., Leura, Bullenmerri, and Gnotuk. Brough Smyth (1858), Bonwick (1858, 1866), Gregory (1903), Grayson and Mahony (1910), Barnard (1911), Searle and Shepard (1915), Singleton (1935), Sussmilch (1937) and Hills (1939*a*, 1940*b*) have commented on these volcanoes.

Mt. Leura (Plate I, figures 1-2). Although previously not recorded as such, Mt. Leura is a caldera, oval in shape and orientated north-south, being about two miles long and one and a half miles wide. It is thus comparable in both size and shape with two other Western District calderas, viz. Tower Hill and Mt. Warrnambool (Gill 1950). Mt. Leura has had two phases—the ash phase, and the cinder phase, in that order. Volcanic activity began by the punching of a vent through the underlying Bullenmerri Clay and the Gnotuk Basalt. A great mass of grey ash and lapilli was ejected, most falling on the southern side of the vent. Indeed, it is now difficult to find bedded grey tuff on the west, north, and east sides of the caldera. There are quarries (Excavations 11 and 12) in basalt on the south and north sides respectively of the Prince's Highway on the N.W. rim of the caldera, and just east of these quarries is the ring fault of the caldera, while just west of them in the road cutting can be seen bedded grey tuff with very fine cinders therein. A considerable area of basalt separates this tuff from the Bullenmerri-Gnotuk spread. Caldera formation has left a high scarp at the southern end of the collapsed area (Plate 2, figs. 3-4), consisting of roughly 50 feet of earlier (pre-caldera) basalt and 40 feet of tuff (measurements by eye only). Between the basalt and the tuff is a well-developed soil. No evidence of any break in the layers of tuff was discovered, and it was concluded that, like most of the ash volcanoes of the Western District, this was a somewhat maar-like kind of activity, being continuous and occupying but a short period of time from a geological point of view. Measurements have not been made, but the volume of ash appears to approximate the volume of the caldera.

Another quarry (Excavation 13) about a quarter of a mile east of Excavation 12, and also on the north side of Prince's

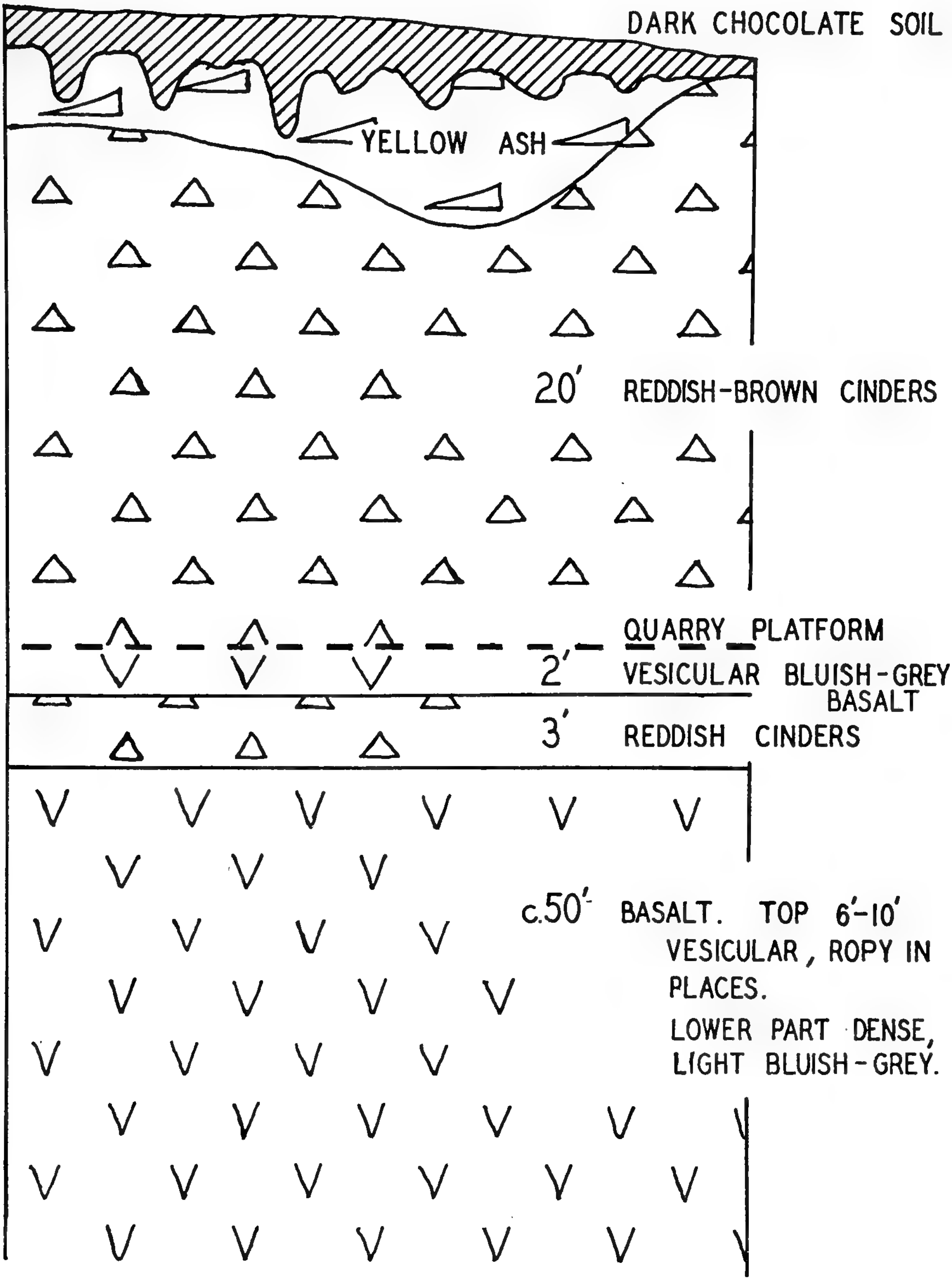

Fig. 2

Diagram of part of the south wall of the large quarry on the north side of Princes Highway, near Mt. Leura (E 13).

Highway, provides an epitome of some of the caldera's post-collapse history. The north end of the wall shows blackish cinders (quarried for roads) dipping at 15° towards the centre of the caldera, and against the truncated ends of these beds is very fresh "later basalt" which is somewhat columnar in places. The junction is a fault line which strikes E.20°S. After the main caldera formation there has been subsidence, causing the cinders to dip inwards to the vent instead of outwards, and faulting the subsequent small flow of basalt against the cinders. On the south wall of the quarry is the succession shown in text figure 2, while text figure 3 shows that on the north wall.

Over both basalt and cinders is a massive yellow tuff with lapilli and angular fragments, contrasting with the earlier grey tuff in both structure and colour. Cinders and yellow tuff can be seen in the road cuttings on the highway east of Excavation 13. A quarry immediately west of the Camperdown Showground reveals some thin flows of later basalt.

Almost opposite Excavation 13 is a quarry (Excavation 14) which is cut into the base of the Mt. Leura cone. As Plate II, figure 3, shows, there is actually a complex of cones, the highest of which is 1,027 feet above sea-level. On the S.W. of the latter is a crater, inset on the edge of which is another high cone. Dawson (1881) records how the aborigines distinguished between these two peaks, called the higher one *Lehuura* (*=nose,* hence the present name *Leura*), and the other *Tuunuunbee heear* (*=moving moving female*). There are over 25 cones in the central complex of Mt. Leura, which is thus a nested caldera. Excavation 14 shows that the cone is made of cinders with numerous volcanic bombs of all sizes from an inch to three feet in diameter. Some of the bombs are of solid basalt, while many have cores of olivine, or iddingsitized olivine (cf. Edwards 1938); a few have cores of anorthoclase and rarely one of country rock is found (cf. Atkinson 1897). On the slopes of the cones are numerous pieces of scoria and ropy lava, and at first sight one is inclined to think that the cones are built of such materials, but it seems that these are rather pieces of spatter thrown out in the dying phases of the volcano's activity.

So the succession of events can be shown to be thus:

1. *Ash phase.* Ejection of grey finely-bedded ash and lapilli (earliest event).
2. *Caldera formation* by collapse (no coarse material can be found in the rim ejectamenta).

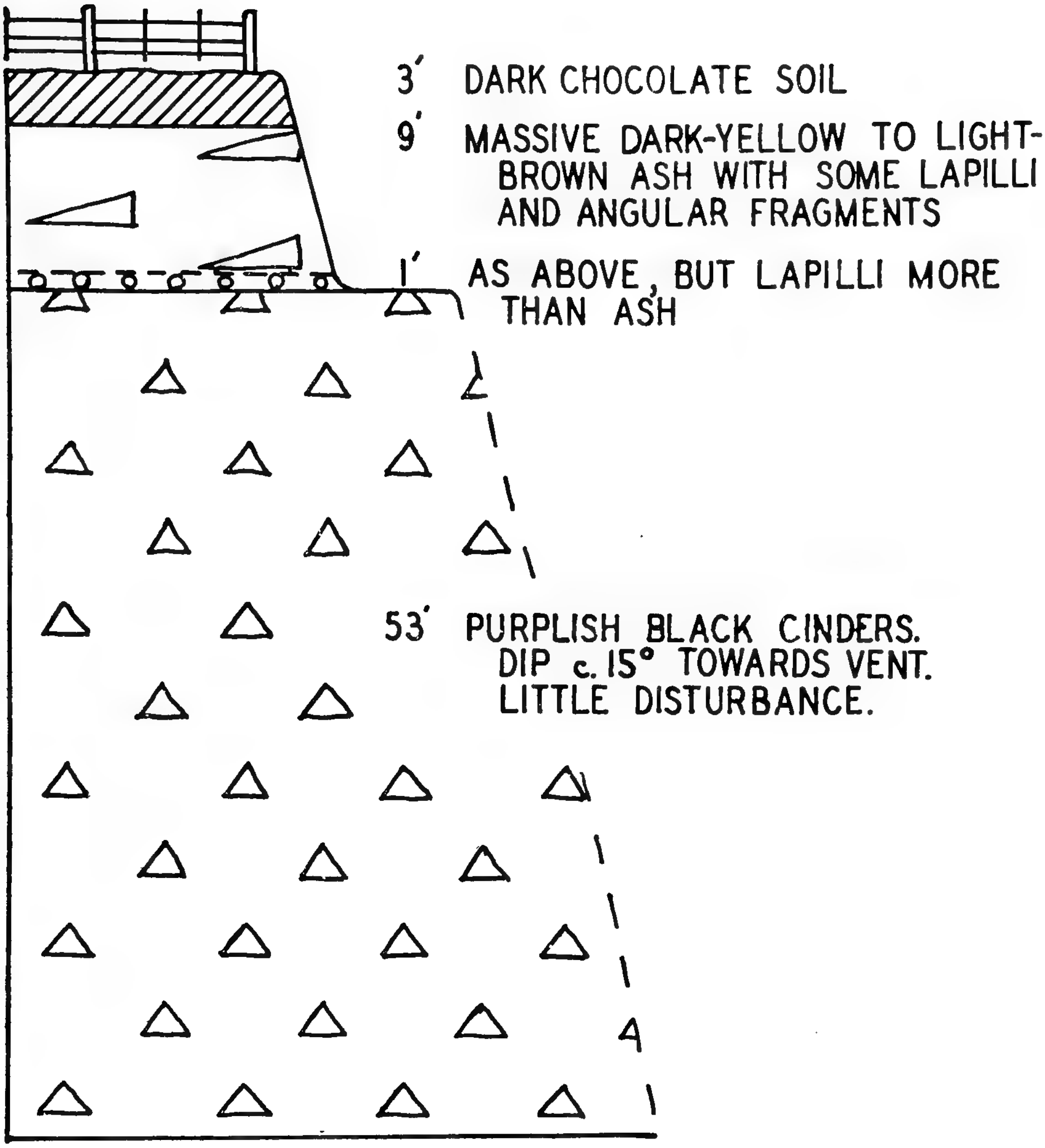

FIG. 3

Diagram of part of the north wall of the large quarry on the north side of Princes Highway, near Mt. Leura (E 13).

3. *Cinder phase.* Illustrated by Excavation 13, which shows—

(a) Ejection of cinders
(b) Subsidence(s) giving cinders vent-wards dip, and causing faults as in Excavation 13, and ridges shown in map (text fig. 1)
(c) First lava flow
(d) Brief ejection of cinders

(e) Second lava flow (see text figure 2)
(f) Further ejection of cinders
(g) Ejection of massive yellow tuff and lapilli (agglomeratic in places)

4. *Formation of soil,* and solution pipes.

For the volcanic rocks formed subsequent to the caldera subsidence (i.e. by event 3 above), the formational name *Leura Volcanics* is proposed. It appears from analogy that the whole series of events 1 to 4 took place in a short space of time, from the geological point of view, but the soils on the Leura Volcanics are surprisingly immature. For this reason there may be a break in time between events 2 and 3, but this would not affect the age of the tuff, which is the main consideration at present.

Volcanoes Bullenmerri and Gnotuk

High steep banks of finely bedded grey tuff on earlier basalt surround these two lakes, which are collapse craters. Lake Gnotuk is about 1¼ miles long and one mile wide, while Lake Bullenmerri is roughly 1½ miles in diameter. The latter is of a curious shape for such a crater, and Hills (1940*b*) has probably rightly suggested that it was formed by the coalescence of three vents.

Most of the tuff from these volcanoes is within half a mile of the crater rim, and fairly evenly distributed around it (like Lake Keilambete), but the original terrain was irregular. The high accumulation of tuff close round these vents, the absence of any signs in the tuff sequence of any intermission in the activity, and also the subsequent collapse, suggest a violent and short-lived vulcanism of the maar type. Between lakes Bullenmerri and Gnotuk there is a low ridge with a channel cut in it, over which the water used to flow in flood time from the higher Lake Bullenmerri to the lower Lake Gnotuk. The aborigines had a name for this (explaining it as due to a Bunyip dragging itself across the ridge, and also for the barely perceptible channel from the north end of Lake Gnotuk to Mt. Emu Creek, whence flood waters ran (Dawson 1881). It is a long time now since enough water accumulated to cause an overflow either from one lake to the other, or from Lake Gnotuk to Mt. Emu Creek, the lower part of which is called Taylor's River in some of the early literature (map opp. p. 39 in Bride 1898).

Order of Eruption

Similar podsol soils have been developed on the grey tuffs at the three volcanoes, which fact suggests that their age is the same or similar.

A section that may be significant is to be seen on the road which rises westwards to the rim from the ridge separating Lakes Bullenmerri and Gnotuk (see text figure 4). The section shows:

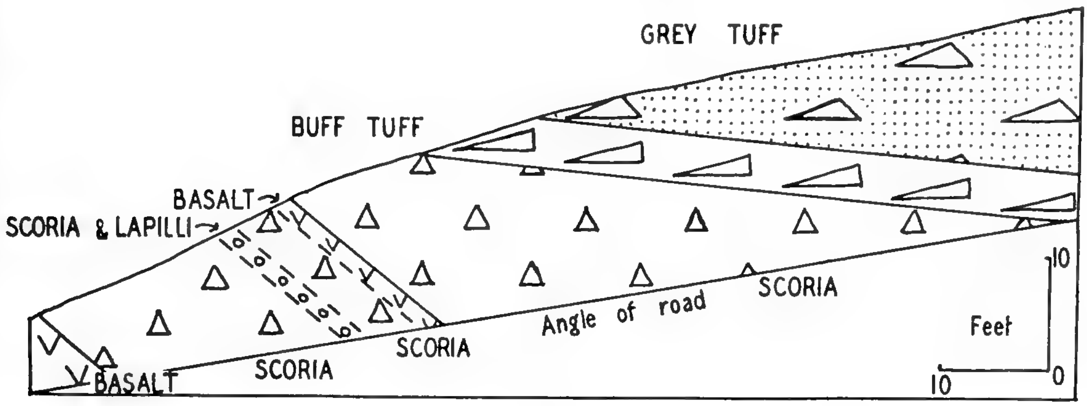

FIG. 4

Section on south side of the road ascending the caldera rim west of the land bridge between Lakes Bullenmerri and Gnotuk.

9. Surface soil (top).
8. About 15 ft. of grey, very finely bedded tuff and lapilli. Strike N. 25° E. and dip 8° W. Similar dip and strike to 7 but not quite the same.
7. 4ft. 6in. yellow to buff tuff. The lower 1 ft. 6 in. is softer and unstratified, while the 3 ft. above is harder and finely stratified. This is finer than the grey tuff above; also it contrasts in having suffered minute displacements. Dip 7° W. Grayson and Mahony (1910, Pl. 4, fig. 2) thought this bed might be a fossil soil.
6. 3 ft. to 15 ft. of reddish scoria occupies an area of change of dip and strike.
5. 1ft. 6in. of solid dark-grey basalt. Dip 25° N.W. and strike about N. 55° E.
4. 4ft. 6in. of reddish scoria merging at the top into scoriaceous basalt, and so to the solid basalt above.
3. 1 ft. 6 in. of reddish scoria and lapilli.
2. About 15 ft. of reddish scoria.
1. Vesicular basalt, six feet only of which is seen in the section. A little further down the hill, the Bullenmerri Calcareous Clay outcrops.

If the yellow tuff is from Mt. Leura (cf. yellow tuff in Excavations 13 and 14), then Leura erupted before Bullenmerri and Gnotuk, whose grey tuff covers the yellow. However, as soil-

forming processes had no time to operate on the yellow tuff before it was covered by the later ejectments, any difference in age is negligible.

The information given about the volcanoes shows that probably ash from Gnotuk largely built the tuff bed now to be seen at the south end of Lake Colongulac. Leura ejected very little grey ash to the north, while that from Bullenmerri and Gnotuk was mostly deposited near the vents especially to the east. As Gnotuk is nearest Lake Colongulac, it probably contributed most ash to that area. The tuff is an important stratigraphical marker in the district.

The Colongulac Loess

Along the S.E. shores of Lake Colongulac are the remnants of dunes over 50 feet high, which Grayson and Mahony called "dunes of re-deposited tuff" on Quarter Sheet 8 N.E. Physiographically, these structures are clearly aeolian, although now considerably modified. Bores 2-4 show that in part at least the dunes were piled against and over low basaltic cliffs, perhaps comparable with those still to be seen on the west shores of the lake. Since they were formed, lake waters have cut cliffs in them twenty to thirty feet high, and streams have cut valleys in them. On their surface a black, silty loam has developed. Lithologically, they consist of a non-stratified, yellow, highly calcareous porous, very fine-grained material with a tendency to vertical cleavage. The rock is light yellow when dry and darker when wet. The rock *in situ* is comparatively dry even in wet winters like that of 1951, but if it becomes puddled with water it becomes sticky, due to the clay minerals present. The black soil on top becomes very sticky in winter. Calcareous concretions are common, and are of any size up to about 2½ inches in diameter. The rock is probably best called loess. Twenhofel (1950) says, "Loess has been variously interpreted, and several different types of materials have at times been included under the term. The present general practice is to limit the term to an aeolian deposit composed of particles of clay and silt dimension." Flint (1947, p. 175) writes, "Loess is a buff-coloured non-indurated sedimentary deposit consisting predominantly of particles of silt size. Commonly it is non-stratified, homogeneous, calcareous and porous, and it may possess a weak vertical structure resembling jointing." The Lake Colongulac rock fits these definitions well, and it is proposed that the formation be known as the *Colongulac Loess* (Plate 3, fig. 5).

The mineralogy of the loess was examined by Dr. A. W. Beasley, who reported that the clay fraction is prominent, and the heavy

mineral percentage small (computed by eye as of the order of 0·05%). The rock is very fine-grained, and most of the grains are rounded. There is a large percentage of quartz. The heavy fraction is chiefly of basaltic origin, and consists largely of black iron ore; it is fairly well sorted and rounded, which shows that the period of time since it was ejected as tuff was not short. Minerals of granitic origin are also present, including zircon. The mineral grains of the loess contrast with those of the tuff in the roundness of the grains and the presence of non-tuff minerals. The loess contrasts with the underlying Chocolyn Silts in that it possesses a greatly increased percentage of basaltic minerals. This is to be expected in view of the intervening basaltic ash vulcanism. The grain size is also slightly larger.*

The Colongulac Loess was once a much more extensive formation than it is now. The present lake has cut cliffs (Plate 3, fig. 5) into the loess which are 20 ft. to 30 ft. high, and have a slope of 32° to 33°. The cliffs are on the windward side of the dunes, and as this is the side of the low angle of dunes, they must originally have stretched far out into what is now the lake. In the middle of the southern shore of the lake there is a headland which Grayson and Mahony mapped as tuff, but excavations proved to consist of loess. The surface slopes southwards towards the shore, and lake waters once surrounded it. There is a small outcrop of basalt at the south end of the west shore of the headland, so this rock may be connected with the formation of the dune at that place. Loess was proved at a number of points in the cliffs of the headland itself, and then an auger hole (Excavation 16) was put down near the foot of the cliff at its northern extremity; it penetrated 6 ft. 3 in. of loess but was still in that formation although below the level of the base of the cliff. On the northern shore of Lake Colongulac there is also a headland; this consists of about ten feet of basalt surmounted by ten feet of loess (represented in the cliff wash by the yellow loess concretions) and black soil. The foregoing facts indicate that there were two lines of dunes when the loess was built up; the first connected what are now the two headlands, and the second is represented by the eroded dunes of the eastern side of the lake. For these to build up, the lake must have disappeared altogether for a considerable period of time,

*Since this paper was written, Prof. F. E. Zeuner has kindly examined a sample of this rock in his London laboratory, and pointed out its variation from the periglacial type of loess found in Europe. He reports: "Its calcium carbonate is as high as 71%. . . . It contains as much as 38% of clay finer than 0.001 mm. . . . It is essentially a clay (44%) with some silt (38%) and about 18% fine sand. There is a concentration on the sand/silt boundary; as much as 15% of the material being between 0.05 and 0.07 mm." The high percentage of $CaCO_3$ is probably due to broken down *Coxiella* shells.

and the old lake floor desiccated to provide the materials. To become so rounded, fine-grained, and well-sorted, the grains must have blown about for a considerable time.

The disposition of the loess shows that it was blown into dunes by N.W. winds, but the prevailing winds at present are S.W. Through the kind help of Mr. J. C. Foley, B.Sc., and Mr. B. W. Newman, B.Sc., of the Commonwealth Meteorological Bureau, I was able to obtain wind analyses for Camperdown covering the years 1946-1950 inclusive, and from these the wind rose shown in text figure 5 was constructed. The analyses are made from

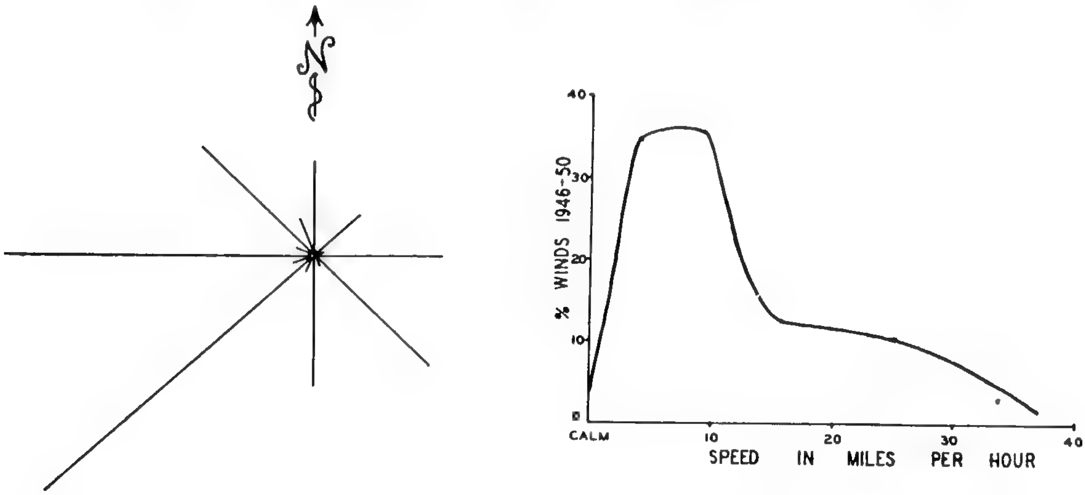

FIG. 5

Wind rose showing directions and relative frequencies of winds at Camperdown during 1946-1950. Graph shows for same period the frequencies of winds of various speeds.

readings taken daily at 9 a.m. from 1946 to 1950; the commonest frequencies were 22·33% S.W., 19·08% W., 9·92% S.E., and 9·75% N.W. From this it is clear that the prevailing winds are S.W., with westerlies next in frequency. The prevailing S.W. winds are well spread over the year. In the driest quarter of the year (January to March), the S.W. winds are twice as frequent as the west winds, and the southerlies are second in frequency. A study of the strengths of the winds shows that 75% were of 12 m.p.h. or less, and that their spread introduces no big variant factor. The west and S.W. winds are a little stronger on the whole than the N.W. winds.

It is therefore clear that the dunes were built when conditions were very different from the present, in that—

1. Lake Colongulac was completely dry for all or practically all the year. In time of drought now when the lake dries up, a little dust accumulates but is washed away by the rain

except in some instances when the farmers take measures to retain it). When the Colongulac Loess was being accumulated, high dunes covered the lake floor.

2. The direction of prevailing winds was dominantly N.W. then, whereas now the prevailing winds are S.W. Of interest is an aboriginal tradition on the origin of the wind which says it came from the N.W. (Bride 1898, pp. 89-90).

Many writers (e.g. Crocker 1941, Browne 1945, Crocker 1946, Crocker and Cotton 1946, Crocker and Wood 1947, Keble 1947) have postulated a mid-Holocene arid period in south-eastern Australia, and this seems to be synchronous with the "Post-glacial Optimum" of other parts of the world (see Zeuner 1945, Brooks 1949, Zeuner 1950, and references). Hough (1950) records evidence from Antarctic bores for the same climatic change. The writer's opinion is that the Colongulac Loess belongs to this period. Beds which are the result of a recent comparatively arid period rest on the eroded 25 ft. emerged marine shell bed on the Moyne River (pp. 74-76), thus linking terrestrial occurrences with a eustatic level and providing a means of extrapolation.

Wishing to make sure that the loess dunes at Lake Colongulac were a function of a general climatic change and not just a local phenomenon, the other occurrences mapped by Grayson and Mahony were examined, as well as the shores of a large number of other lakes including Lake Corangamite, the largest lake in Victoria. Both north and south of Pelican Point over many miles of the eastern shore of Lake Corangamite, similar dunes were observed. For instance, a road cutting on the Dreeite North road, about a mile south of the Cundare turn-off (Colac 4 mls. = 1 in. military map grid reference 637, 295), yellowish loess can be seen resting on stony rises (basalt). Farther north, in a road cutting (Beeac 1 ml. = 1 in. military map grid reference 628,956), similar material is to be seen but full of broken *Coxiella* shells.

The study of the loess dunes involves the question of their relationship, if any, to the lunettes so named by Hills (1940*a*), who considered these ridges to be formed by precipitation of atmospheric dust by spray from the lakes. This implies a period more pluvial than the present, a time when the basins (on the east sides of which these crescentic ridges stand) were filled with water. When discussing these structures, Hills (1939*b*, p. 31 2) referred to the dunes at Lake Colongulac and Lake Kariah. Stephens and Crocker (1946) described lunettes from Tasmania, Victoria, New South Wales, South Australia, and Western Australia, but considered them to be purely aeolian structures built in a period more arid than the present. This interpretation had

previously been put forward with some hesitation by Harris (1938). In U.S.A. similar loam ridges have long been known as "clay dunes", and recently Huffman and Price (1949) have described in more detail the process by which they are being built now in Texas. Granules of clayey material are stripped from the edges of mud-crack polygons and piled into transverse ridges; subsequent wetting causes the clay to consolidate and so establish the dune. These dunes are thus a result of comparatively arid conditions. The Texas clay dunes have both sides with about equal degree of slope (20:1 windward and 25:1 leeward in the example given), which may well be due to flowage when the clay granules are wet by rain and so distributed on the dune surface. In the lunettes described by Hills and by Stephens and Crocker, the windward side is often comparatively steep and the leeward side comparatively flat—the opposite of what is normal in purely aeolian dunes, and different from what is to be seen in the American "clay dunes". It is possible that there is some analogy here with the Lake Colongulac dunes. The lunettes may have been built up in an arid period, then the windward sides steepened by lacustrine erosion when the basins filled with water in a succeeding pluvial period. It appears to the writer that the N.W. Victorian lunettes and the Lake Colongulac loess dunes are genetically related, and were built during the same arid period, but differ on account of the differing materials and environment in the two areas. The Lake Colongulac dunes are not lunettes in that they lack the characteristic crescentic shape, but lunettes do occur in the area, e.g. on S.E. sides of small shallow lakes (called salt pans on the 1 in. = 1 ml. military map) about 3 miles E.S.E. of Mortlake (see N.W. corner, Quarter Sheet 8 N.E.). When away from tuff beds as these lakes are, the dunes are more clayey.

Upper Holocene Pluvial Period

On the east side of Lake Colongulac are two creeks, one just north of the "Chocolyn" homestead and called Chocolyn Creek on the map (text figure 1), and another half a mile farther N.E. called Windmill Creek on the map. In these creeks there is a high level alluvium up to about ten feet above H.W.M., which for convenience is hereafter referred to as the ten-foot terrace. Much of the terrace at the mouth of Windmill Creek is only seven feet about H.W.M., but has suffered more erosion than Chocolyn Creek which is restricted at its mouth. An attempt was made to benefit from this by building a dam there, but the next flood washed it away. The ten-foot terrace has been incised since the lake level fell (Pl. 3, fig. 6). In addition to the high-level alluvium

in the creeks, a platform found variously in silt, tuff and basalt is to be seen in a number of places round the lake shore. For example, near Excavation 4 on the south side of the lake there is a well-defined terrace at 9·1 ft. (average of three readings) above H.W.M. On the east side of Lake Kariah there is a similar terrace at 9 ft. above H.W.M. Detailed work has not been done on these terraces, but there is ample evidence to show that since the loess dunes were built, there has been a maintained level of the lake approximately 10 ft. higher than the highest level in living memory. Since the earliest historical record in 1843 there has always been a "beach" consisting of part of the former lake floor (see Adeney in Owen 1877, pp. 184-185). A rise of 10 ft. in the level of a shallow consequent lake is a lot, especially as it would cause the lake to spread over a greater area.

One can only conclude that since the arid period there has been a time of greater rainfall than the present. High level terraces cut in loess are found round other Western District lakes, and are well marked on the east side of Lake Corangamite, the largest lake of all. Alluvium representing former (often anastomosing) lakes and swamps are shown on the map (text figure 1). The thick bed of black clay overlying a limestone band in the Moyne River section (pp. 74-76) is no doubt largely an expression of the same phase. In many places in the Western District there are peat deposits (no longer forming to any appreciable degree) resting on clays (e.g. Errey 1896, Gill 1947*b*). The present climatic trend appears to be toward the arid rather than the pluvial side.

If the Colongulac Loess is mid-Holocene as argued above, then the soil developed thereupon, and the alluvia developed since that time are Upper Holocene. The Hampden Tuff belongs to a period before the lake water began to dry up, and indeed to a time when the lake was maintained at about 10 ft. above H.W.M. As the lake was deeper and more extensive then, the period must have been even more pluvious than during the Upper Holocene 10 ft. level. Although the vulcanism itself may have been short-lived, a considerable period of time is involved in the lithification of the volcanic ash, and then the erosion of the resultant tuff so as to present cliffs along the southern shore of the lake. Since the loess dunes were built, the tuff has been eroded back something like a chain. It is not unreasonable to suggest that it would take as long or longer for the tuff to be eroded to where it was when the loess dunes were built. If this be correct, then the vulcanism occurred about the dawn of the Holocene or the close of the Pleistocene, when the effects of the last glacial period were disappearing. The rounded nature of the grains of tuff materials in the

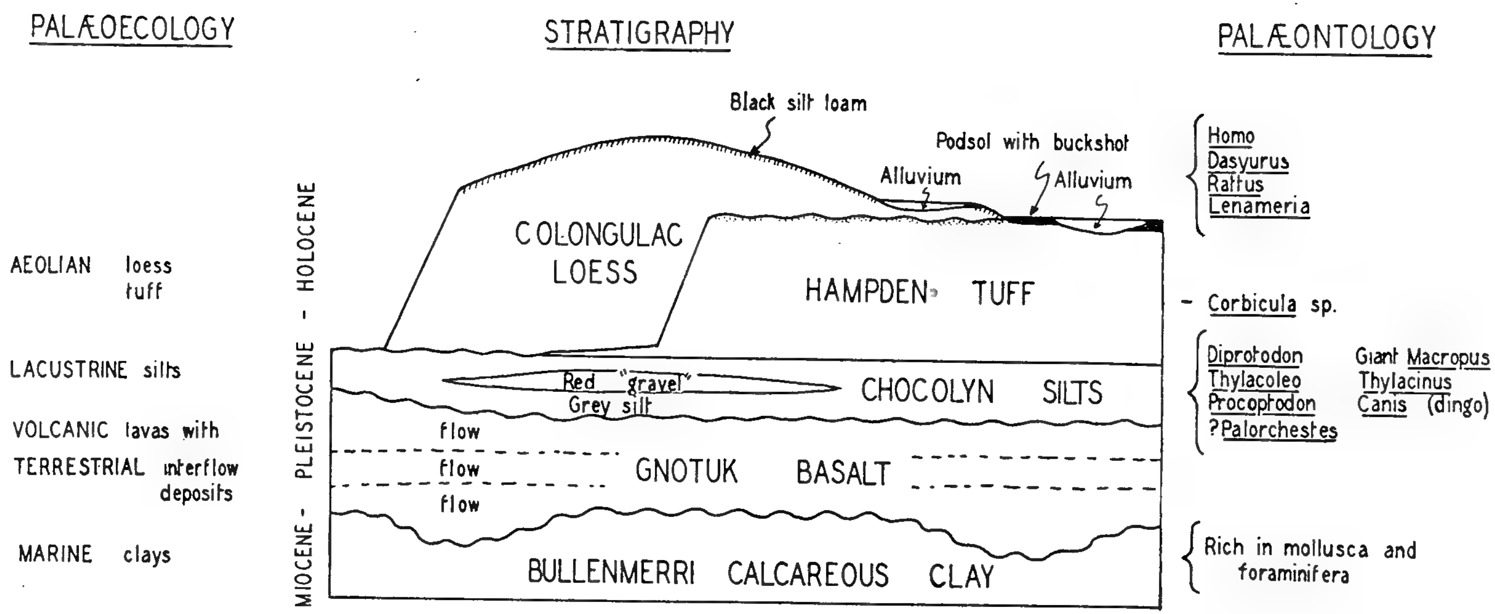

Fig. 6

Diagram of the geology of the Lake Colongulac area.

Colongulac Loess also indicate the lapse of a considerable span of time between the vulcanism and the building of the dunes. The Chocolyn Silts were deposited prior to that, and the bones in them suffered a couple of cycles of erosion and deposition. It is therefore considered that the animals of which they are the remains lived during late Pleistocene time. The geology of Lake Colongulac is diagrammatically presented in text figure 6.

Evidence of Pleistocene Aboriginal Occupation

Associated with the late Pleistocene extinct marsupial fauna at Lake Colongulac, there has been found evidence of human occupation in the form of (a) a dingo jaw, and (b) a cut bone. Both have the characteristic preservation of bones from that horizon, and (as shown earlier in the paper) there is no other bed from which they could have come.

(*a*) *Dingo jaw.* This fossil was described originally by McCoy (1882). Wood Jones (1921) and others (cf. Brazenor 1950, p. 83) have made it clear that the only way the dingo could have reached Australia was by being ferried here by the aborigines. The Tasmanian aborigines had no dingo, but readily took to the dogs introduced by white people. Also the dingo has not been found fossil in Tasmania. We therefore can say the mainland aborigines brought the dingo. If the Tasmanian aborigines passed over the Australian mainland, then the dingo was brought to this continent later than the passage through it of the Tasmanians. Dawson (1881, p. 89) has told how the aborigines of Western Victoria prized their dingoes and used them in hunting. Boldrewood (1896, pp. 40, 122) and Dawson have referred to the many wild dingoes that existed in the area when white people first came.

As the presence of dingo in a geological horizon in Australia means the presence of the aborigine at that time, it can be used as a means of determining the antiquity of the aborigines. It is therefore of interest to note where the dingo has been found fossil. It was found in the Wellington Caves, N.S.W. (Mahony 1943, p. 24) when shafts were sunk in the bone-breccia whence came *Diprotodon, Nototherium* and *Thylacoleo.* Mahony (1943, pp. 25-26) has reviewed the discussion concerning an alleged human tooth from there, and since then Finlayson (1949) has amassed evidence for the rejection of its supposed human origin. Owen and many writers since have expressed regret that no human remains have been found with the extinct marsupials at Wellington Caves, but if the presence of dingo means the presence of aborigines in the land at the same time, then the desired evidence is there after all. Association of man with the extinct

giant marsupial fauna is recorded from Pejark Marsh, Victoria (Keble 1947), Forbes, N.S.W. (Andrews 1910, Mahony 1943), and Lake Menindie, N.S.W. (Movius 1940), as well as at the Wellington Caves and Lake Colongulac as described above. Fossil dingoes have also been found in the Murray River valley (Hale and Tindale 1930), and in the Tantanoola Caves, S.A. (Tindale 1934). In the National Museum of Victoria are dingo bones from the following Victorian localities—Gisborne, Bairnsdale, Meredith, Colac, and Bushfield (p. 72). *Canis familiaris dingo* has stratigraphical value as a fossil, being indicative of Upper Pleistocene or Holocene age.

(b) *A cut bone,* known as the *Colongulac Bone,* has been described by Spencer and Walcott (1911), Keble (1947), and the writer (Gill 1951*b*). It consists of the fourth metatarsal of a giant kangaroo (*?Palorchestes*), whose matrix and preservation show that it came from the Chocolyn Silts, whence came the dingo jaw and the bones of the extinct marsupials. Spencer and Walcott first thought the Colongulac Bone was human workmanship, but finally (although with some misgiving) included it among bones which they claimed had been chewed by *Thylacoleo,* the so-called marsupial lion. The cuts comprise two wedge-shaped incisions which meet on the side of the bone, and appear to be an attempt to remove the head. The bone is not crushed, but pieces removed; it has therefore not been chopped but cut. Removal of bone without crushing, and the forming of two precisely confluent cuts (the bottoms of which make an angle of 72°) is impossible for an animal. In any case, it is widely held now that *Thylacoleo* was not a carnivore, and no reason suggests itself why an animal should attempt to remove the head of a metatarsal. On the other hand, an aboriginal might attempt to do so as a stage in the manufacure of an implement or ornament. Mr. H. V. V. Noone examined the bone and drew attention to some fine ridges on the sides of the cuts, and to undercutting on the side of one incision. He pointed out that neither of these features is consistent with chewing by *Thylacoleo,* but both are consistent with work by an aboriginal tool. They suggest a sawing motion and not a squeezing one as when an animal bites. The Colongulac Bone was collected by William Adeney, the first white settler at the lake where it was found, and the cuts were made before the bone was mineralized. If not made by an animal (which hypothesis is rejected), the cuts must have been made by an aborigine (see also Gill 1952).

(c) *Ecology.* There are certain aspects of the occurrence of the bones at Lake Colongulac that call for explanation. Firstly,

the bones are much broken. Jaws are plentiful, but no complete skulls. A mutilated skull of *Thylacoleo* (the type) is the only skull known from the lake. Most of the fragments are pieces of limb bones, no whole ones have been seen. If we exclude *Thylacoleo* (for which there is good reason), there is no predator or scavenger of the times, no carnivore, which could chew these bones and so fragment them. As the adjacent countryside is so very flat, and the bones have not been transported far, the fragmentation cannot be attributed to fracture in transport. Another possibility is that other animals trampled on them and so broke them. This is likely to happen if the bones are at a watering hole on a creek or similar site, but they do not occur in such a situation. The animals would not drink from the lake, as it was salty then, as shown by the presence of fossil *Coxiella.* Any breaks made in the bones in extracting them from their matrix, or since, are readily recognizable, and cannot be confused with breaks that occurred before mineralization. With this and related problems in mind, hundreds of bones and fragments of bones were collected from sub-recent middens at Tower Hill beach, between Warrnambool and Port Fairy (Gill 1951*a*). It was noted that no complete skulls and rarely any whole limb bones were found, although pieces of such were common. Dawson (1881, p. 18), in his account of the aborigines of Western Victoria, says, "Skulls and bones are split up, and the brains and marrow roasted".

Secondly, the bones are very localized in occurrence. Those from Excavation 2 came from an area not exceeding a chain in diameter. In a letter to Owen, Adeney described how the bones were numerous and scattered thickly over the beach near where he lived. In both cases, the sites are near creeks of that time, but not on them. The original sites of the bones were probably on the basalt cliffs or rises beside the lake, and the red gravel in which some of the bones occur suggests silts impregnated with iron oxide from the weathering of the basalt. Such sites are what one would expect aboriginals to choose for camps, being near water and yet affording a good lookout.

In the author's opinion, there is insufficient evidence to prove what the original ecology of these bones was, but they could have been part of a midden site. Such an interpretation fits the presence of dingo and cut bone. If the site is a midden, it means that the aborigines used *Diprotodon, Procoptodon, Thylacoleo,* etc., for food. In the Pleistocene there were both large and small marsupials, as fossiliferous beds show, but it is noteworthy that at Lake Colongulac only the giant forms are present in the Chocolyn Silts. This indicates some kind of selection. If the bones are the

remains of a midden, it shows that the aborigines hunted the big heavy marsupials in preference to the smaller forms. The giant species would be easier to catch because less agile and each success in the hunt would yield a much bigger volume of food. With the passing of the giant marsupials, the aborigines would have to adapt themselves to changes in food-fauna as well as to climatic changes.

Evidence of Mid-Holocene Aboriginal Occupation

The greater part of the skeleton of an aborigine was found in the Mid-Holocene ancient dune formation called the Colongulac Loess. The site has been mapped (Gill 1951*b*); it is on the east side of Lake Colongulac between Excavation 2 and Chocolyn Creek. It is suggested that the skeleton be known as the *Colongulac Skeleton*. Professor S. Sunderland and Dr. L. J. Ray, of the Department of Anatomy, University of Melbourne, have kindly examined the bones, and report as follows:

Sex. Female.

Age. No epiphysial remains can be seen in any of the long bones. The skull is not present, but three teeth are included and these show a high degree of attrition, so it must be concluded that the skeleton is that of an adult of at least middle age.

General. The general condition of those bones present is good, although most of them show various degrees of damage.

A full list of the bones is provided in Appendix I to this paper, and it will be noted that they comprise the limb bones except for a humerus, the pelvic girdle but no pectoral girdle, only six vertebrae, some rib fragments, and three teeth but no skull. The bones are yellowish in colour, like the containing loess, and appear to be slightly leached.

The Colongulac Skeleton was found in the side of the cliff (32° slope) cut by a former high lake level. The cliff is about 25 ft. high, and the skeleton was dug out half-way up the cliff. When the Colongulac Loess was being searched for fossils, the only success was at the place where the skeleton was ultimately found. The jaw of a native cat, *Dasyurus viverrinus,* an incisor tooth and bone of a rat, and two phalanges were discovered. The Mammalogist at the National Museum of Victoria, Mr. C. W. Brazenor, identified the phalanges as human. By the time of the next visit to the locality, erosion had brought to view the ends of a couple of bones, and careful excavation was made, the bones enumerated in the appendix being discovered. They were photographed *in situ* before removal, as shown in Plate 4, fig. 7. The position of the bones is reminiscent of a flexed burial, but on the other hand most of the light bones had been scattered or had

disappeared altogether, and the skull, pectoral girdle, and one humerus are missing. The skeleton could not be a recent burial from the top of the one-time dune, because it is too deep, and it is not easy material to excavate, like sand is. Nor was a burial effected into the side of the cliff, because if this were done, the black clayey soil washed from the top over the surface of the cliff could not but be mixed with the underlying yellow loess, whereas the bones were in a homogeneous matrix, as can be seen in the photograph. Probably the skeleton was buried originally when the dune was about half built, but the blowing of the dune material by the wind has uncovered the skeleton, scattering the lighter bones, and perhaps the missing skull, pectoral girdle, and humerus were decomposed by exposure at that time, only a few teeth remaining. Whether that was the fate of those bones or not is necessarily conjecture, but the attitude of the preserved bones suggests a flexed burial uncovered and then re-buried in a disturbed condition, such as we see taking place with bones on coastal dunes in our own time. The antiquity of the Colongulac Skeleton is the age of the loess formation in which it occurs. In other words, it is mid-Holocene, something like 5,000 years old.

Other Evidences of Aboriginal Occupation

In an earlier paper (Gill 1951*b*), some artefacts from Lake Colongulac were recorded, and since then another semi-circular quartzite artefact was found on the east side of the loess headland on the south shore of the lake. It was accompanied by numerous sharp-edged milky quartz flakes, obviously imported and not occurring naturally. Similar flakes, and a rough basalt axe which had also been used as a grindstone, were found by the writer on the ridge on which the "Carinya" homestead stands on the Mortlake Road north of Lake Gnotuk. Mr. Woodmason, who has a property on the south side of the lake on the Hampden Tuff, reports ploughing up an aboriginal skull near the lake. Mr. P. Law Smith kindly donated to the Museum a basalt boulder with two mill-holes in it, and one grinder, found on the "Chocolyn" estate. In the surrounding district numerous ground-edge axes have been found in the soil, and Casey (1936) has recorded an unusual type of implement dug up at Tallindert near Camperdown. Aborigines were living in the area when white people came (Dawson 1881, Kenyon 1930).

Thus there is evidence at Lake Colongulac of aboriginal occupation in the pluvial period prior to the ejection of the Hampden Tuff (Late Pleistocene), and in the succeeding Arid Period (Mid-Holocene), and since then up to the time of arrival of Europeans.

There is no reason to doubt that the aborigines lived more or less continuously in the district throughout the time represented.

2. Pejark Marsh

The general geology of this area has been mapped by Grayson and Mahony (1910), while Spencer and Walcott (1911, and as recorded in Keble 1947) provide an account of the finding of an aboriginal millstone under the tuff. Mahony *et al.* (1936) expressed some doubt on the matter (see also Mahony 1943), but Keble (1947) made an excavation which put the succession beyond all doubt. The millstone came from below bones of *Diprotodon optatum,* proving that the aborigines were there in the time of the giant marsupials. The site is in section XVI (1), Parish of Terang, and the geological section is as shown in text figure 7. The various formations, in order from the surface, will now be commented upon.

Alluvium and Tuff

About a quarter of a mile N.E. of the site, a spade hole was dug for three feet into the superficial alluvium, and it was found to be rich in the shells of the freshwater snail *Lenameria tenuistriata* (Sowerby). The Terang Tuff which underlies this alluvium can be traced continuously from Lake Terang, which is a crater lake, to Pejark Marsh, and it undoubtedly came from that volcano. Bonwick (1858, p. 35) gives the following well-log from the Terang township:

Black soil	3 feet
Ash-stone (= tuff)	5 feet
Clay	2 feet
Sandy clay	5 feet
	15 feet

Walcott (1919) discussed whether the tuff has been re-deposited or not. The purity of the tuff, its fine regular stratification, and the manner in which it flattened swamp reeds indicates that the tuff is largely where it fell. If it were re-deposited at any considerable interval of time after the eruption, it would be mixed with other sediments.

High in the tuff at the S.E. corner of Pejark Marsh (Excavation 17), a few specimens of *Coxiella* were found, and this suggests that the water into which the tuff fell was brackish, contrasting with the freshness of the present marsh. The fairly long history

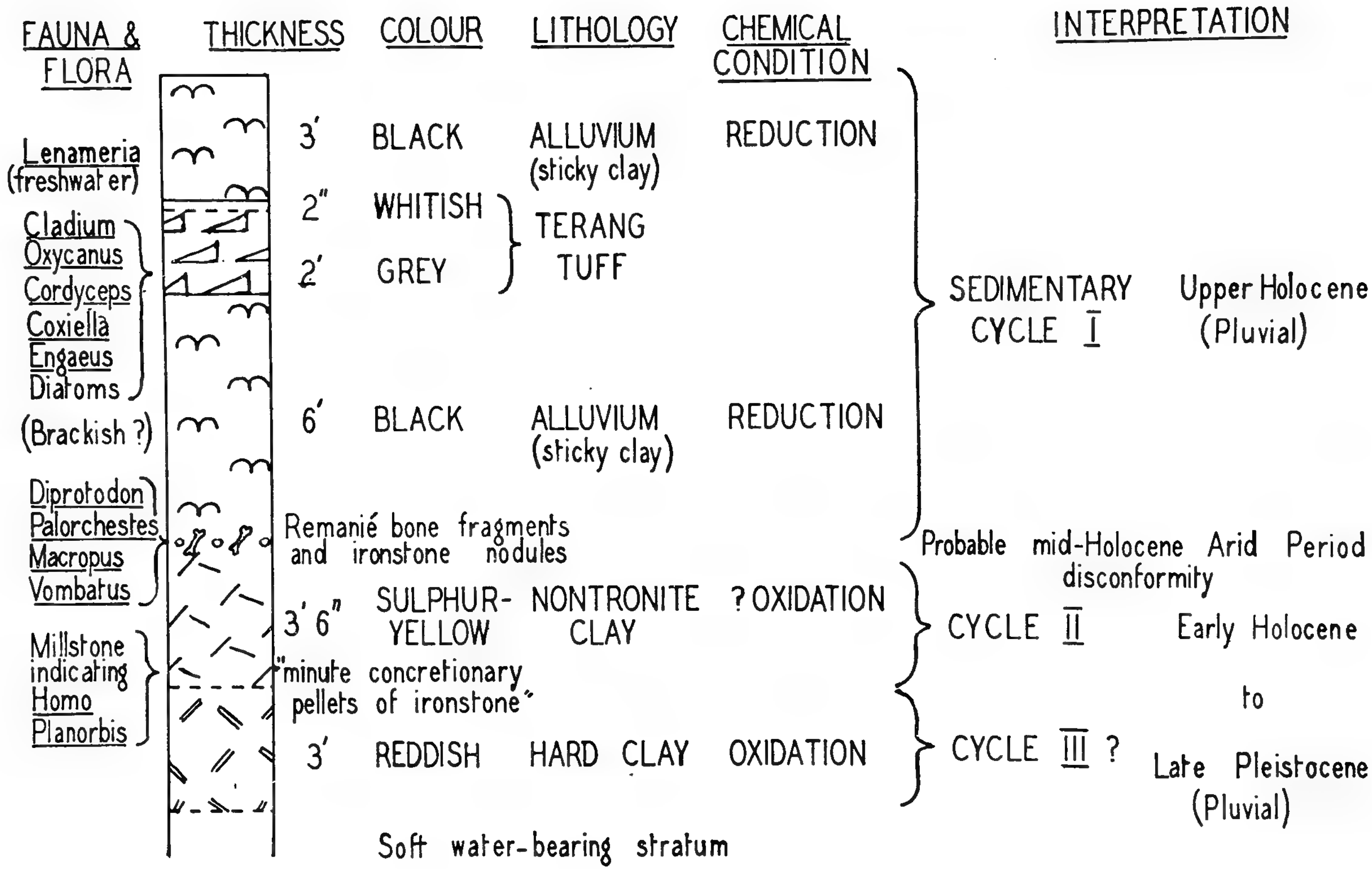

FIG. 7
Summary of the geology of the Pejark Marsh site, and its interpretation.

of the swamp makes it quite possible that the waters were brackish, and Mr. J. H. Willis of the National Herbarium tells me that this is not inconsistent, on present knowledge, with the occurrence of *Cladium tetragonum* which is recorded from the base of the tuff, although little is really known of the ecology of this plant. Chapman (in Spencer and Walcott 1911, p. 4) recorded 'fresh-water diatoms' from this tuff, but most diatoms have a broad range of tolerance. Moreover, the range of salinity of which *Coxiella* is tolerant is not known, but the form is recorded from Boneo Swamp (Chapman 1919), and the writer has collected it from Lake Bullenmerri which is only mildly saline (relative salinity, sea 100, Bullenmerri 18·4—Anderson 1941, p. 149). Skeats and James (1937) reported *Coxiella* in tuff at Lake Corangamite.

Lake Keilambete, 2½ miles N.W. from the site, is a maar-like caldera, the ejected material being comparable in volume with the size of the crater. The nearby Lake Terang is a similar feature but more complex. The high ground on the S.W. side of the lake consists of poorly-bedded yellow tuff with abundant lapilli, judging by the cemetery excavations and spoil heaps of rabbit burrows.

Walcott (1919) says a well near the cemetery passed through eighty feet of tuff. Further east on the south side of the lake, the ground quickly loses elevation but the slopes become steeper; this is due to the rocks there being volcanic agglomerate consisting of coarse lapilli, scoria, and basalt. The so-called Mt. Terang, a low hill on the N.W. side of the lake, is the only other comparatively high pile of volcanic material. On the west side of it is a crater, and on the N.E. side a quarry reveals finely bedded grey tuff and lapilli dipping up to 9° N.E., overlain by a few thin flows of basalt. The direction of the dip shows that the tuff came from the nearby crater, and not the Lake Terang caldera. Grey tuff can also be seen in the north bank of the lake, next the Scout Hall, and it is this rock which is found at the Pejark Marsh site a little under a mile away (see text figure 8). The detailed history of the eruption has not been worked out because not important for the present purpose. However, enough was done to show that the eruption was a short and rather violent one, ejecting a comparatively small quantity of volcanic material, and culminating in the subsidence of an area half a mile by over three-quarters of a mile. The Terang Tuff occurs over the southern end of Pejark Marsh, as the following spade and auger holes (see text figure 8 for locations) show, but how far north it extends has not been ascertained.

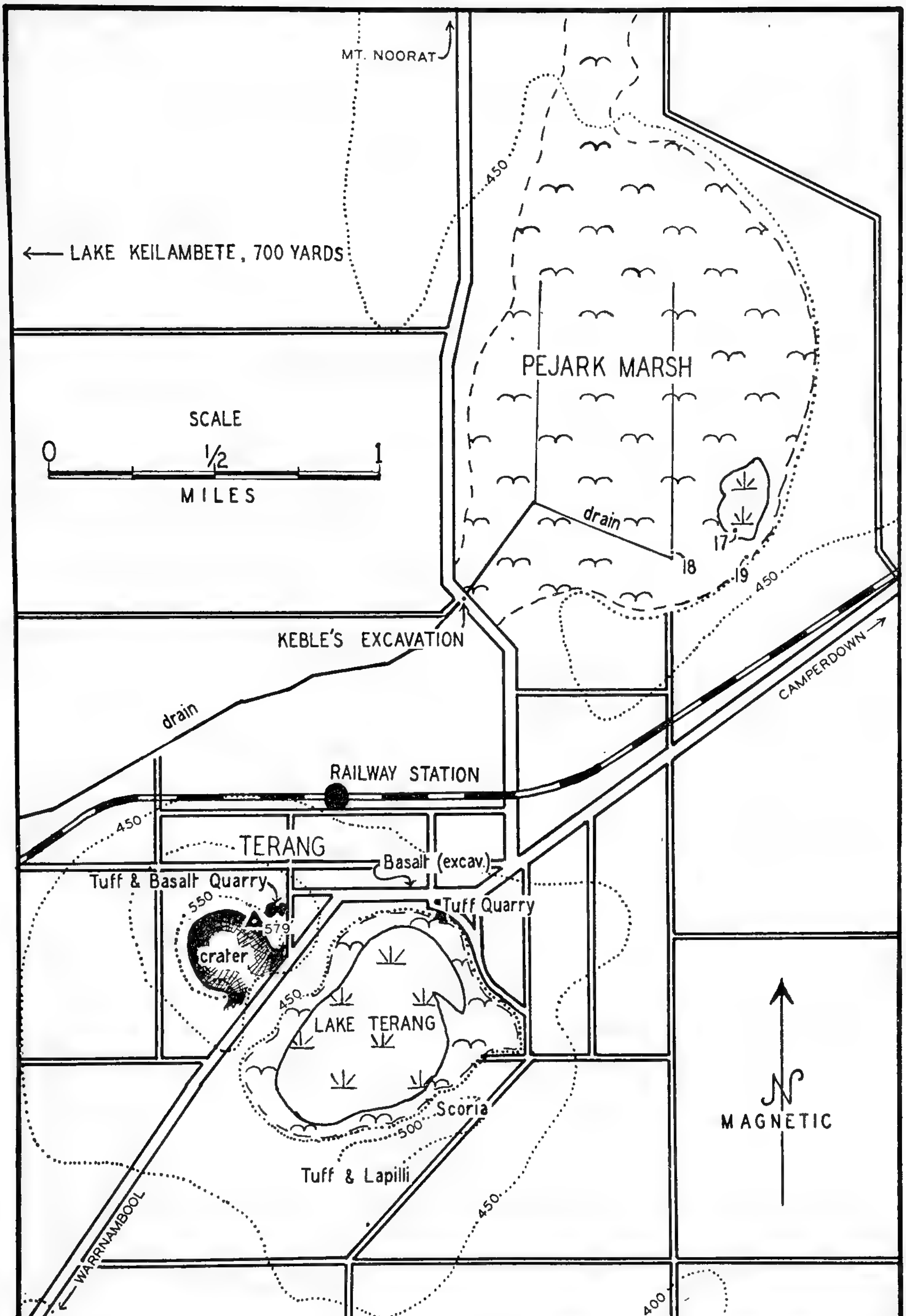

FIG. 8

Map showing the location and relationships of the Pejark Marsh site. The figures 17, 18 and 19 refer to excavation sites mentioned in the text.

Excavation 17. Lowest part of S.E. corner of Pejark Marsh.

6 in. black peaty loam
6 in. dark grey to black silty clay with *Lenameria*
Brownish tuff with *Coxiella* (not penetrated)

Excavation 18. South end of Pejark Marsh near corner of main drain.

1 ft. 0 in. black loam
$\frac{1}{2}$ in. calcareous concretionary layer
1 ft. 3 in. grey tuffaceous alluvium
3 ft. 0 in. fairly pure, brownish-grey tuff with occasional cross-bedding; fossil reeds
3 ft. 0 in. bluish-black alluvium (not penetrated)

The calcareous layer is a secondary deposition and hard enough to be used by the owner of the property as paving stones for garden paths. Fossil reeds were found in the basal layers of the tuff, like those reported by Spencer and Walcott (1911) and Keble (1947) in their excavations further west.

Age of Terang Tuff

Search was made for evidence of the age of the vulcanism that yielded the tuff at Pejark Marsh, and the following observations were made:

1. A skull of *Dasyurus viverrinus,* the extant native cat, preserved in tuff, was found in the National Museum, having been discovered in a cutting made for the bowling green in the Public Park beside Lake Terang.

2. The soil on Mt. Terang is thin and rocky, an immature dark-brown loam contrasting with the mature soil on the tuff at Camperdown. It has no buckshot gravel like the Camperdown podsol. Soils on basalt and on tuff in the township have been observed and they are likewise immature, with a negligible amount of ironstone nodules. No soil pipes have been seen in any of the profiles.

3. Both Lake Terang and Pejark Marsh are fresh, and contrast with the very salt Lake Colongulac. It has long been recognized that the accumulation of salt in a lake is a function of time. Formerly, the explanation has generally been that salts were derived by solution from the country rock, then concentrated in lakes by evaporation. Anderson (1941, 1945) has now shown, however, that the earlier explanation is inadequate, the waters deriving most of their saltness from "cyclic salt", i.e. salt in water swept up by winds racing over the whipped-up surface of stormy seas, then deposited in rain. Woodcock (1950) has measured the amount of salt in the air at a shoreline location.

The lakes of the Western District vary from fresh to saltier than the sea. Lake Terang, although a crater lake, has never been deep. Bonwick (1858, p. 34) claimed that "it has an average depth of forty feet, without an outlet. The variation of level does not exceed three feet." Walcott (1919) records, "It is said that when the early settlers came to Terang there were thirty feet or more of water in Lake Terang, and that it even flowed out through the gap in the S.W. side." "The greatest depth of water (in 1909) was said to be three feet." Grayson and Mahony (1910) said the lake was then already partly swamp. The Australian Handbook for 1897 (p. 294) says, "Lake Terang teems with fish". It is now dry in summer and a swamp in winter. A few years ago, during a drought, the peat on its floor caught fire and burned for about a year. Lake Terang has always been fresh, and this is interpreted as evidence of the lake being so recent that it has collected no appreciable amount of cyclic salt. The same applies to Pejark Marsh.

4. In discussing the Colongulac Loess, mention was made of the fact that the majority of shallow lakes and the swamps have windblown silts or clays on their S.E. borders—a result, it is believed, of the mid-Holocene arid period. Lake Terang and Pejark Marsh are exceptional in that they have no such aeolian structures. This fact is taken to mean that the volcano and the post-tuff form of the Marsh came into existence after the arid period. Set within the steep banks of the S.E. corner of the Marsh is higher ground which could be windblown material covered by tuff. An auger hole on this elevated ground passed through three feet of dark-brown soil and one foot of partly decomposed tuff before being stopped by solid tuff (Excavation 19).

It is to be concluded from the foregoing evidence that the Lake Terang volcano erupted comparatively recently, and in age is to be compared with Tower Hill rather than with the crater lakes Bullenmerri and Gnotuk near Camperdown. Such an age determination fits in well with the rest of the evidence.

Alluvium under Tuff

The nature of the alluvium under the tuff in Excavation 18 indicates that the conditions of deposition were the same or similar to those yielding the alluvium above the tuff. The volcanic eruption interrupted the slow deposition of the swamp alluvium which at present (and even more so in the near past) is the expression of comparatively pluvial conditions. In that the thickness of the alluvium over the tuff is half that under the tuff, it may be inferred in the circumstances that the period of deposition

is roughly of the order of half that of the lower bed. The alluvium under the tuff shows that the swamp is older than the vulcanism, and not caused by it blocking the local drainage. The alluvium under the tuff and that over it belong to the one sedimentary cycle.

From the bottom of this black clay bed under the tuff Keble obtained bones including teeth of *Diprotodon optatum*. Similarly, Spencer and Walcott record that "Just at the junction of the two clays the majority of bones occurred" (1911, p. 93). No better assurance could be desired that the bones were *in situ* than that they were discovered under the finely-stratified tuff. This rock is so hard as to be difficult to disturb, and when it has been disturbed, the fact is obvious. The fauna so far determined is:

Diprotodon optatum Owen
Palorchestes cf. *azael* Owen
Macropus cf. *titan* Owen
Vombatus sp.

Most of the bones are fragments which Spencer and Walcott at first thought had been fragmented by aborigines, but later decided were the work of *Thylacoleo carnifex*. However, *Thylacoleo* was almost certainly not a carnivore. The bones were broken before mineralization. The country is so flat that even in flood time there could hardly be forces sufficient to fragment the bones to this extent. The possibilities remaining are fracture by the feet of other wild animals and/or by the aborigines.

Probable Disconformity

Although there is no marked break between the black clay and the underlying yellow clay, the cumulative effect of the following evidence strongly suggests that there is a disconformity at that level.

(a) *Condition of the bones*. The black clay is "highly carbonaceous", and as one would expect in a swamp, in a state of chemical reduction. On the other hand the bones are red and highly mineralized. Bones in swamp deposits as at Bushfield are black due to chemical reduction, so the bones at Pejark Marsh could not have reached their present condition in that setting. Both the bones collected by Spencer and Walcott and those collected by Keble are red, highly mineralized, and very polished. As the bones occur at the junction of the two clays, it may be inferred that the bones were mineralized in oxidizing conditions (the red being taken to be iron oxide) at a time when the swamp was dry, i.e. it was not a swamp at all. As shown by the geological history of some other fossil bones, and by that of buckshot gravel, such iron oxide is remarkably stable.

(b) *Aggregation of bones.* Keble found bones only at the base of the black clay, and Spencer and Walcott said nearly all theirs came from the junction of the two clays. If the silt (or whatever the material was) in which the bones were mineralized were blown away, then when swamp conditions came, bringing about the deposition of the black clay, the bones would be aggregated at the base of the new bed.

(c) *Presence of ironstone nodules.* Keble shows a layer of ironstone nodules at the junction of the black and yellow clays, and this is probably a residuum (buckshot) from a soil dispersed before the black clay was deposited. The mid-Holocene arid period could have dried up the lake or swamp, and dispersed the soil, concentrating both bones and ironstone gravel.

(d) *Presence of fossil roots.* "In the upper part of the yellow clay are also seen fine black fibrous impressions left by rootlets sent down by plants" (Spencer and Walcott 1911).

(e) *Lithological Change.* With the fossils from Pejark Marsh at the National Museum there was found a piece of the yellow clay which underlies the sub-tuff black alluvium. It was noted that the clay was not the common limonite-yellow but a decided sulphur-yellow. The clay did not effervesce in HCl; it turned brownish-red on ignition (but without smell of sulphur), and gave a negative silver-coin test. A sample was submitted to Mr. A. J. Gaskin, M.Sc., of the University of Melbourne, who determined the yellow material as the bentonite mineral *nontronite* which is greenish in colour but oxidizes yellow very readily. Nontronite develops under stagnant water reducing conditions, and is derived probably from the contiguous earlier plains basalt. All who observed the clay *in situ* (including experienced field geologists) referred to it as a yellow and not greenish clay; this suggests that the clay had already been oxidized. It would be in keeping with the rest of the evidence to think of the nontronite clay as having been deposited in a swamp under reducing conditions, then oxidized when the swamp dried up in the arid period. Part of a *Planorbis* was found in this clay, indicating a freshwater environment (slide P15656).

Underneath the yellow clay is a hard red clay which may belong to a third and yet older cycle of sedimentation. Spencer and Walcott mention "minute concretionary pellets of limonite", which suggests buckshot formation.

Age of Aboriginal Occupation

The evidence for occupation is a millstone found in the yellow nontronite clay. If the interpretation given above be correct, then

the fragmental remanié bones of extinct giant marsupials were aggregated from an earlier bed on the top of the yellow clay during the mid-Holocene arid period. That earlier bed may well have been an eroded part of the yellow clay, because Merry records (in Keble 1947, p. 47) numerous bones therefrom. In any case the aborigines were in the Terang area at the time of the existence there of the giant extinct marsupial fauna. The yellow clay would be laid down in a lake or swamp under reducing conditions, and this ecology indicates the early Holocene or late Pleistocene when the country was emerging from the last glacial period. It seems that most of our present swamps were built up during the recent pluvial period, while the earlier swamps were built up during the pre-arid pluvial period, represented by the Chocolyn Silts at Lake Colongulac.

Many surface evidences of recent aboriginal occupation have been reported in the area. Local residents have dug up aboriginal stone axes on the higher ground just north of the Pejark Marsh site. Further north at Glenormiston a skeleton has been found (Gill and Manning 1950). Bonwick (1858) and Dawson (1891) have given accounts of the aborigines present when Europeans arrived.

3. Bushfield

Keble (1947, pp. 56-58) recorded a basaltic axe found in tuffaceous limestone under tuff in a terrace of the Merri River, near Bushfield, north of Warrnambool, Western Victoria (see text figure 9). With the aboriginal axe were found bones of *Macropus* and *Vombatus* which are mineralized, dense black, and with shiny surface, which are no doubt due to preservation in conditions of chemical reduction.

The tuff is from the Tower Hill volcano. In this area, about eight miles from the vent, the falls of ash were comparatively small, and so little tuff is found on the high ground, most of what fell there being washed into the steeply incised river course. The ash appears to have blocked the river somewhat, resulting in strong cross-bedding of the tuff. It would appear that interference with the flow of the river caused local swampy or lake conditions to prevail, so that a good deal of calcareous matter (including the snail shells *Lenameria acutispira* and *Lymnaea brazieri*) accumulated with the tuff. However, the volcanic ash soon fell so frequently that beds of pure ash covered the more calcareous lower layers. The site was investigated by the writer, and a section (text figure 10) surveyed across the river and through the place where the excavation was made. The river

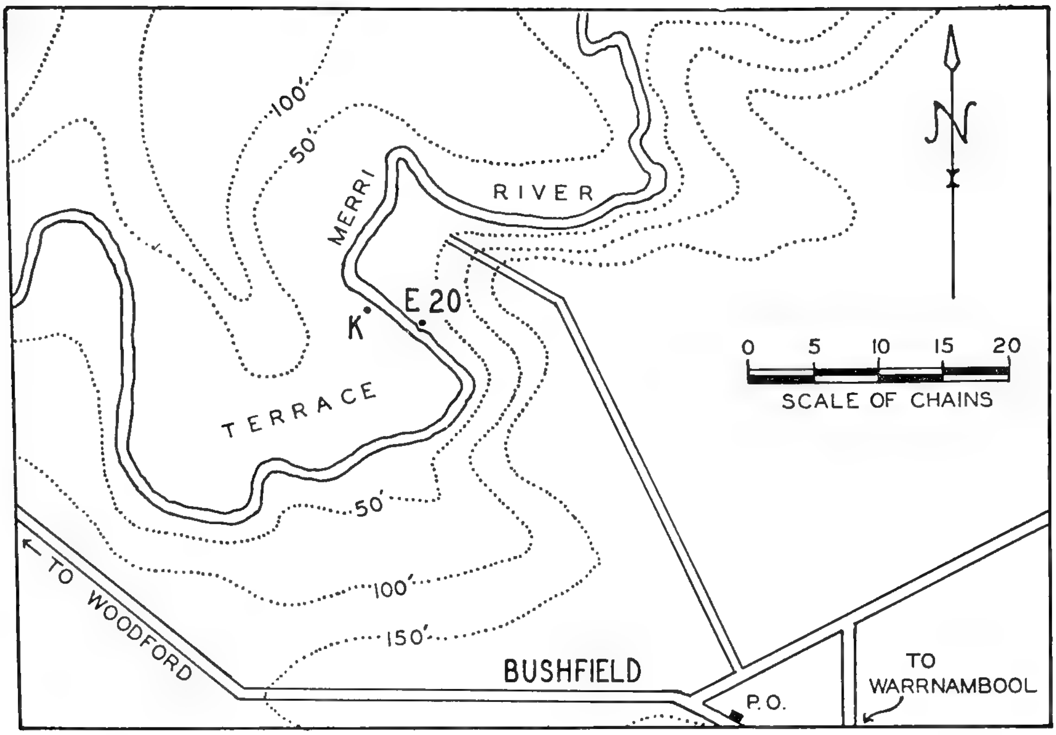

FIG. 9
Map showing the location of the Bushfield site. E 20 is the excavation shown also in Fig. 11.

sections of tuff were searched for the calcareous layer with the fossil snails, but without success; it was covered, or the horizon is a lenticle cutting out so as not to appear in the river section. Nor could any bones be found in the tuff. However, four and a half chains downstream from the excavation there is a platform on the left bank were the sub-tuff light-grey clay outcrops, held together by the roots of old trees, as shown in text-figure 11. A spade hole (Excavation 20) proved the clay for four feet beneath

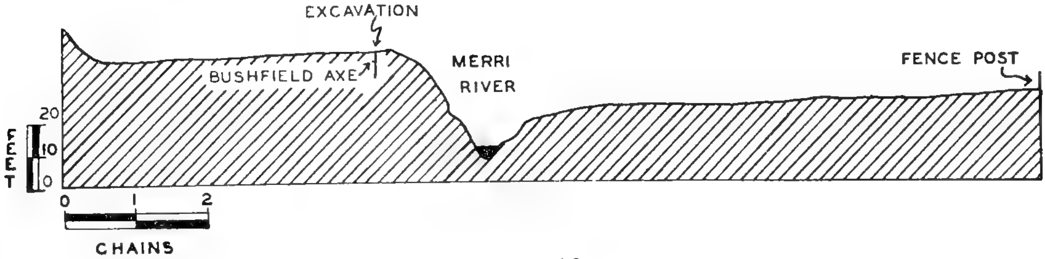

FIG. 10
River terraces, Bushfield site. Surveyed section from the end of the nearby road (see Fig. 9) through the excavation from which came the Bushfield axe.

the tuff. Scour hollows in this platform have been filled by the river with quartz gravel and re-deposited clay, and the sediments were found to contain numerous bones in exactly the same condition as those accompanying the axe, i.e. mineralized, black, and shiny. The walls of the valley consist of Miocene marine limestone capped with basalt, so the bones can only come from the tuff or under it. The fauna comprises living animals only, and the National Museum Mammalogist, Mr. C. W. Brazenor, kindly

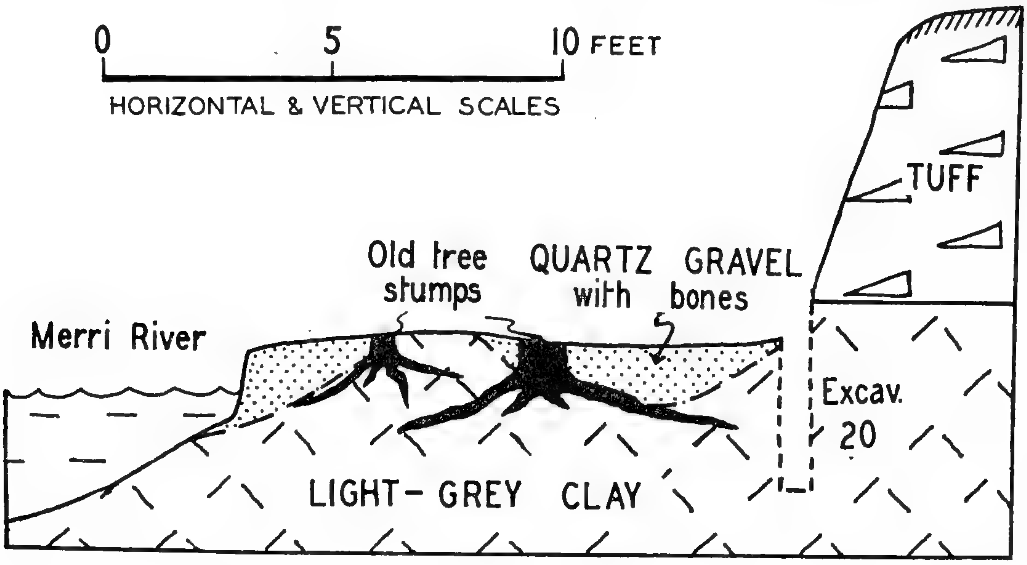

FIG. 11

Section of east bank of Merri River at Bushfield, showing the bone-bed and Excavation 20 (see Fig. 9).

identified them as follows:

Canis familiaris dingo Blumenbach ..	Dingo
Sarcophilus harrisii (Boitard)	Tasmanian Devil
Dasyurus viverrinus (Shaw)	Native Cat
Sminthopsis sp.	Pouched Mouse
Isoodon obesulus (Shaw)	Short-nosed Bandicoot
Trichosurus vulpeculus (Kerr)	Silver-grey Possum
Pseudocheirus laniginosus (Gould) ..	Ringtail Possum
Vombatus hirsutus (Perry)	Wombat
Potorous tridactylus (Kerr)	Dark Rat-Kangaroo
Wallabia bicolor (Desmarest)	Black-tailed Wallaby
Wallabia rufogrisea (Desmarest)	Red-necked Wallaby or Brush Kangaroo
Macropus canguru (Müller)	Captain Cook's Kangaroo (= Great grey or forester)
Mastacomys fuscus Thomas	Broad-toothed Rat
Rattus assimilis (Gould)	Allied Rat

This fossil locality has been visited regularly for some years, and as far as one can tell, the supply of bones is not being renewed by river action. The river was searched for a mile downstream but no fossils found. Upstream a few have been found opposite the excavation site, and a few chains further upstream again a few small bones, chiefly *Rattus,* have been discovered. It seems that in cutting through the tuff, the river has eroded the bed containing bones such as discovered in association with the Bushfield Axe, and many of these fossils were caught in the natural trap of the old platform a few chains downstream. It is clear from the condition of the bones that they have not travelled very far. Along with the fossil bones, the writer found a number of aboriginal flint and bone implements, and these were passed to the National Museum Ethnologist, Mr. D. J. Tugby, for study.

Age of Aboriginal Occupation

The presence of dingo bones proves the presence of aborigines in the country in addition to the evidence of the Bushfield Axe. Coming from under lithified tuff, there is no doubt about the axe and bones recorded by Keble being *in situ.* The marsupial bones, found by Keble, belong to living species, as do all the bones found by the writer. This indicates that the occupation is a later one than those at Lake Colongulac and Pejark Marsh, where there are the bones of the extinct giant marsupials.

Archibald (1894) discussed the antiquity of the aborigines of the Warrnambool district, and claimed this to be considerable

(a) because of alleged human imprints in the aeolianite on which the city is built. The interpretation of the prints as human has been much doubted (*vide* Officer 1891, Dennant 1891, 1892, McDowell 1899, Pritchard 1895, Stirling *et. al.* 1903-1904, Gregory 1904, Brancho 1905, Noetling 1907, Klaatsch 1906, 1908, Mulder 1909, Daley 1910, Chapman 1914, Gill 1943, Mahony 1943). Through the kindness of Mr. Charles Foyle at Warrnambool, I have been able to obtain a copy of a very sharp photograph taken at the time. That impressions were made by something is indubitable, but that they were made by humans is doubtful, and quite inadequate when it is the sole evidence.

(b) because of the finding of stone axes with hafting grooves. When white people arrived in the area, the aborigines were using non-grooved diorite axes. The grooved ones are much rarer, are generally of some rock other than diorite, and are often found in circumstances suggesting antiquity. There is a good deal of evidence to support Archibald's opinion, and it is of interest to note that the Bushfield axe is of basalt and possesses a hafting-groove. The Ballarat implement (see Mahony 1943, p. 41) is a patinated pointed implement with hafting-groove found at a depth of 22 inches at Ballarat in undisturbed gravelly clay. Recently, a large felspar porphyry axe 4½ inches wide, 6½ inches long (incomplete), and 1½ inches thick, from Gerangamete in the Otway Ranges was presented to the Museum by Mr. E. R. Rotherham (reg. no. 47906). It has been weathered to a depth of about half a centimetre since manufacture,

and was found at a depth of three feet in whitish pipeclay when a well was being sunk by Messrs. C. and J. Grant on their property two miles west of Yaugher railway station and half a mile east of the West Barwon River. Like the Bushfield Axe and the Ballarat Implement, the Gerangamete Axe possesses a hafting groove.

As the Bushfield Axe, flint implements, and fossil bones came from the Tower Hill Tuff, their age must be that of the tuff, which will now therefore be discussed.

Age of the Tower Hill Tuff

A general account of the geology of the Warrnambool area has been previously given (Gill 1943) and the age of the Tower Hill Tuff discussed (Gill 1950*a*), wherein it was pointed out that the sea must have receded from a higher level to about where it is now by the time the Tower Hill volcano erupted. Since then a greater area has been mapped, and a more detailed study made, resulting in the following information.

1. *Evidence from Eustatic Sea Levels*

Following lines laid down earlier (Fairbridge and Gill 1947), a study was made of the emerged shell beds from Peterborough to Portland with special attention to the Warrnambool-Port Fairy area. This is not the place to enter into a detailed account of these, but in brief the findings are—

(a) There are extensive, horizontally-bedded emerged shell-beds laid down by a sea about 25 feet higher than the present one. It was a warmer sea, as indicated by the presence of four genera of subtropical foraminifera (Collins 1953), and by the mollusca, which include *Anadara trapezia* and *Ninella torquata*. These beds are now widely travertinized and penetrated by solution pipes no longer active. The 25-ft. sea is believed to represent a late Pleistocene eustatic level widely reported throughout the world. It was followed by a sea-level much lower than the present one when deep gorges were cut by coastal rivers. When the sea returned from this low level, the valleys were infilled with silt. In addition to the depositional evidence of the 25-ft. sea, there is erosional evidence represented by platforms cut in Pleistocene aeolianite and other rocks. The low sea-level is no doubt that of the last glacial. The Tower Hill Tuff is found resting on the 25-ft. sea shell-beds. An instructive section is to be seen on the Moyne River (see also Collins 1953) where the 25-ft. shell bed has been eroded as far as a basalt bar would allow, and then as the sea came up again, blocking of the drainage caused deposition of very fine sediment, viz. clay, and of limestone, which means comparative absence of

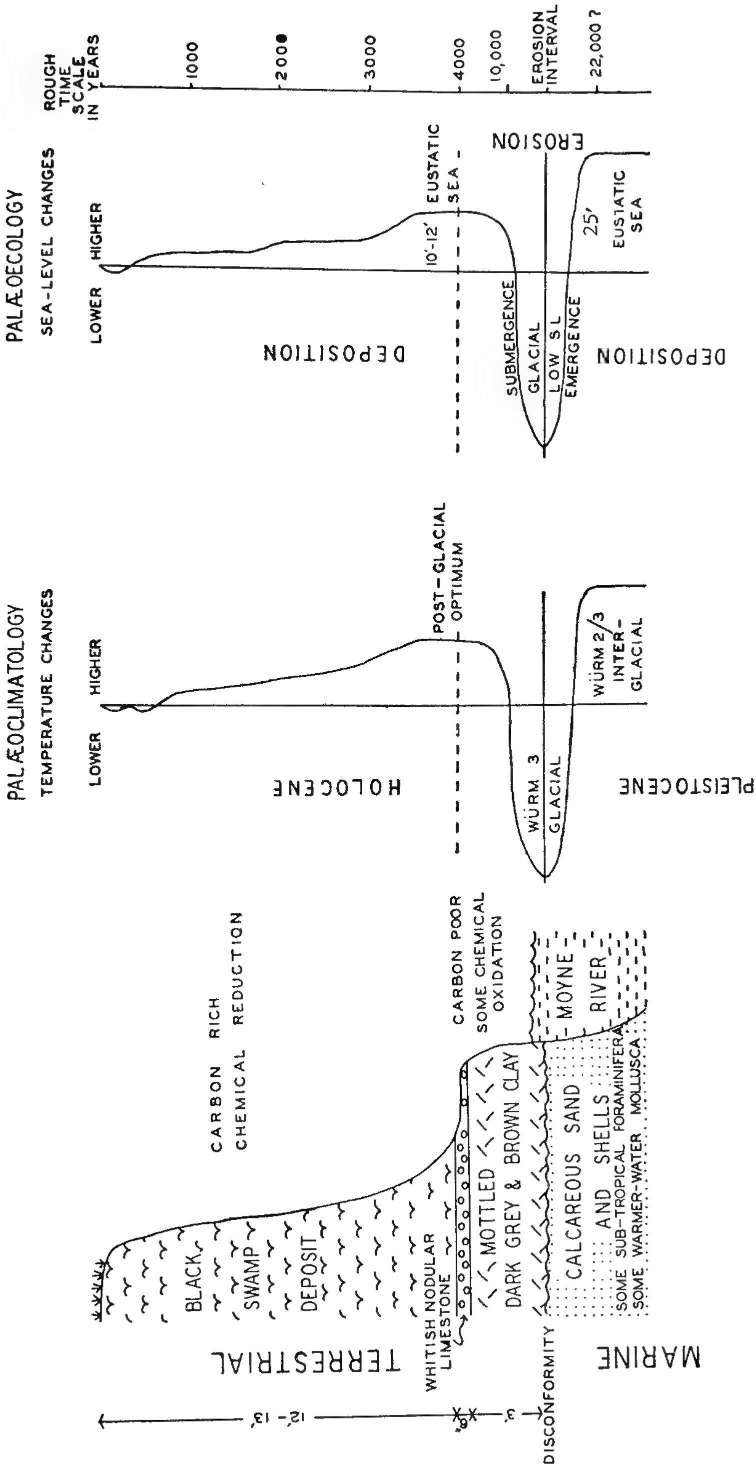

FIG. 12

Section on the right bank of the Moyne River, Rosebrook, and its interpretation.

terrigenous material. The presence of Hystrichosphaeridae (Cookson 1953) in the brown clay is evidence of the proximity of the sea, as also is the frequent occurrence of chenopodiacean pollen—probably *Salicornia,* the salt bush. The brown clay thus presents a brackish water facies in contrast with the freshwater facies of the overlying black alluvium, with which the Tower Hill Tuff is associated. The black clay is poor in plant microfossils, only fern spores being recognized.

The limestone band occurs at the junction of the two clays and consists of very irregular off-white nodules of re-crystallized calcite. A slide (P15253) showed a cryptocrystalline structure, but neither in the slide nor by other methods could Mr. B. Tindale find any diatoms. Professor G. W. Leeper examined the section and did not think the limestone a pedological feature because limited so precisely to the junction between the two clays, which although different in colour are very similar in texture. It is suggested that the lower clay was deposited in the times of the ten-foot sea when this area was probably a saline swamp. When the sea began to retreat, the swamp would drain and the clay be oxidized by the air, because the climate then was arid compared with the present. If a small lake (perhaps seasonal) existed in this low-lying area, its fauna could provide the limestone, which since then has completely recrystallized. With the onset of more pluvial conditions, the black alluvium began to be deposited, and this process still continues. The Tower Hill Tuff is associated with this alluvium (see page 81). It is therefore later than the ten-foot sea (which conclusion is supported by observations elsewhere), and associated with the present cycle of deposition.

(b) The ten-foot* eustatic level of the sea cut shore-platforms as can be seen along the coast (Gill 1947*b*), and in embayments, e.g. behind the beach at Warrnambool, east of Pertobe Road, where there is the remnants of a platform in aeolianite 10·6 feet above low-water Warrnambool Harbour. Depositional as well as erosional evidence of this sea is to be found in the form of shell beds which are not travertinized or pierced by solution pipes. (In some earlier papers the 25-foot and 10-foot levels have been run in together and referred to as a 15-foot level.) Teichert (1946, 1950) and Fairbridge (1947*a,* 1948, 1950) have described evidence of 25-foot and 10-foot eustatic sea-levels in Western Australia, but have been able also to establish 5-foot and 2-foot stages in the retreat of the 10-foot sea. Conditions in the area studied provide

*The ten-foot, five-foot and two-foot eustatic levels are so named following Fairbridge 1950.

special opportunities for recording such small differences, and although these conditions do not apply in the Warrnambool-Port Fairy area, there are features which would fit well such an interpretation. The writer thinks that the sea went a short distance below the present level before rising very recently to where it is now (Gill 1950*b*), and there is evidence that it is still rising (Gutenberg 1941, Fairbridge 1947*b*, Teichert 1947; cf. Hanson 1934, Dyson 1948, etc.).

(c) Cannon Hill and Lighthouse Sections, Warrnambool. More detailed work has been done on these since the earlier description (Gill 1950*a*). At Cannon Hill three auger holes were put down as shown in text-figure 13. The first auger hole (Excavation 24) was put down approximately 6 chains 45 feet west of the west fenceline of Pertobe Road, and 20 feet north of the north fence-line of the railway. The surface of this point is 13·3 feet and the bottom of the auger hole 4·5 feet above low-water Warrnambool harbour.

4 ft. 4 in.	tuff and black loamy soil
1 ft. 0 in.	dark-greyish to blackish sand with swamp fossils
1 ft. 3 in.	greyish-brown sand
2 ft. 3 in.	reddish for a few inches then bright red clayey sand
0½ in.	yellow aeolianite
8 ft. 10½ in.	Total depth

At the top of the reddish clayey sand *Melliteryx helmsi* (Hedley) and *Austropyrgus buccinoides* (Quoy and Gaimard) were obtained. The second auger hole (Excavation 25) was put down approximately 6 chains 29 feet west of the west fenceline of Pertobe Road, and 18 ft. 6 in. south of the north fenceline of the railway. The surface at this point is 8·2 ft. and the bottom of the auger hole 4·2 ft. above low-water.

9 in.	black clayey sand with swamp fossils
3 in.	brownish sand and marine shells running into above
2 ft. 6 in.	greyish, very compact sand
6 in.	red sandy soil
0½ in.	yellow aeolianite
4 ft. 0½ in.	Total depth

A third auger hole (Excavation 26) was put down in line with Excavations 24 and 25, and approximately half-way between the railway line and the south fenceline of the railway. The surface at this point is 4·6 ft. and the bottom of the auger hole 0·4 ft. above low-water.

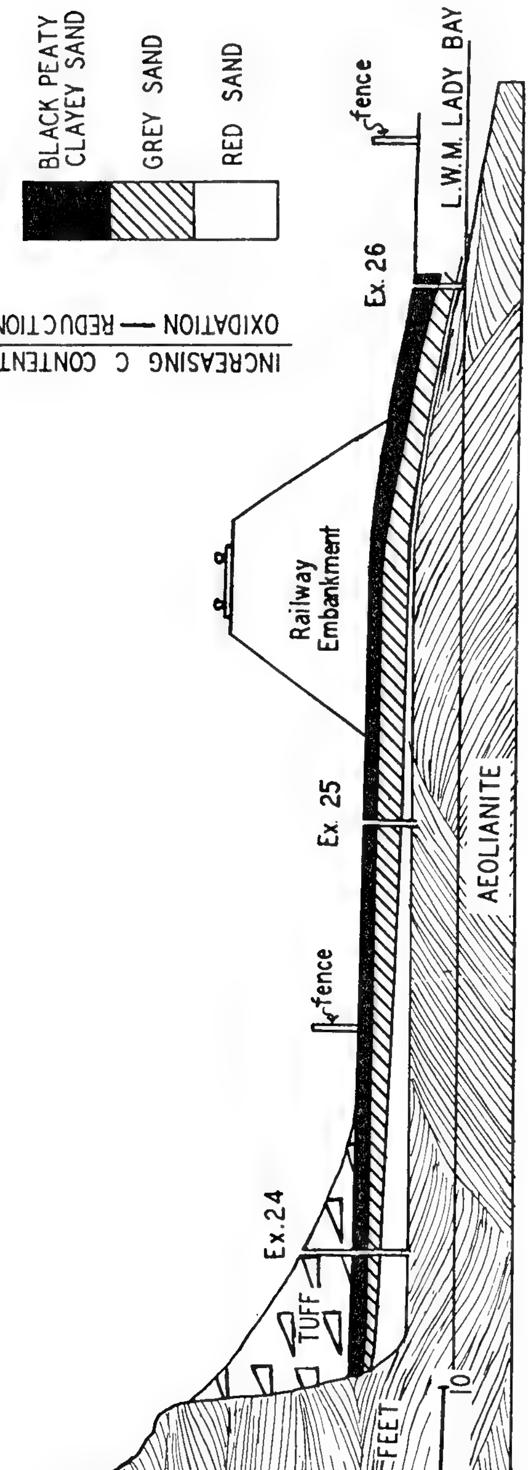

FIG. 13

Cross-section at Cannon Hill, Warrnambool, at site shown in Fig. 12.

Swamp facies	4 in.	black alluvium with some brownish patches
	11 in.	black alluvium with numerous swamp fossils
Mixed facies	6 in.	grey clayey sand with swamp fossils, and occasional marine shells
	2 in.	same matrix with numerous marine fossils, swamp shells, and plant remains intermixed
	1 in.	hard, light-grey concretionary band
	1 ft. 11 in.	brownish-grey sand with fragments of marine shells
Terrestrial facies	3 in.	red sandy soil
Marine platform	0½in.	yellow aeolianite
	4 ft. 2½in.	Total depth

The fauna of the band at 21 in. to 23 in. includes *Bythinella* which is a marsh and estuarine mud flat shell, *Notospisula trigonella* which is found on salty sandy mud beside beaches, and marine shells such as *Austrocochlea obtusa porcata* (a mud flat species kindly determined by Mrs. A. N. Carter), *Batillaria australis, Bembicium auratum* (sandy-mud dwellers), *Macoma deltoidalis* (sand dweller), *Mysella donaciformis, Mytilus* (rock-dweller), *Ostraea,* and *Zeacumantus cerithium.* In addition there is *Melliteryx helmsi* (Hedley) found in the top two inches of silt in Lake Pertobe at present. This mixture of facies shows that some shells have been washed in.

The datum used in these surveys is low-water Warrnambool harbour, fixed about 1925 when the local sewerage scheme was being introduced. The tidal range on the open coast is something like six feet (not measured), while the calculated mean tidal range in the harbour is 2·34 feet. Warrnambool or Lady Bay appears open to the sea, but it has a submerged bay bar of aeolianite (see Admiralty Chart). Slightly higher eustatic levels would be affected by the bay bar (probably higher then if the sea has been lower in the meantime), so low-water Warrnambool harbour is a better datum to use than low-water on the open coast.

The section below the lighthouse was explored by an auger hole (Excavation 27) which was put down 1 chain 55 feet west of the east fenceline of the railway (approximately on the line of section B in Gill 1950*a*). The surface at this point is 12·6 feet and the bottom 3·2 feet above low-water. This suggests the presence of the same buried aeolianite platform proved in the Cannon Hill section. When Lake Pertobe dried up in May 1950, a sample of the top two inches of sediment was collected and found to contain *Melliteryx helmsi* (Hedley), *Austropyrgus buccinoides* (Quoy and

Gaimard), and *Laevilitorina mariae* (Tennison Woods). The first two were found in Excavation 24 just above the fossil red soil, and the first in Excavation 26 at a depth of 22 inches. *Austropyrgus buccinoides* is found in freshwater habitats, such as on the Merri River near the Bushfield Axe site, and in brackish water habitats, but not in marine habitats. The occurrence of true marine shells mixed with swamp shells and plants in the Cannon Hill

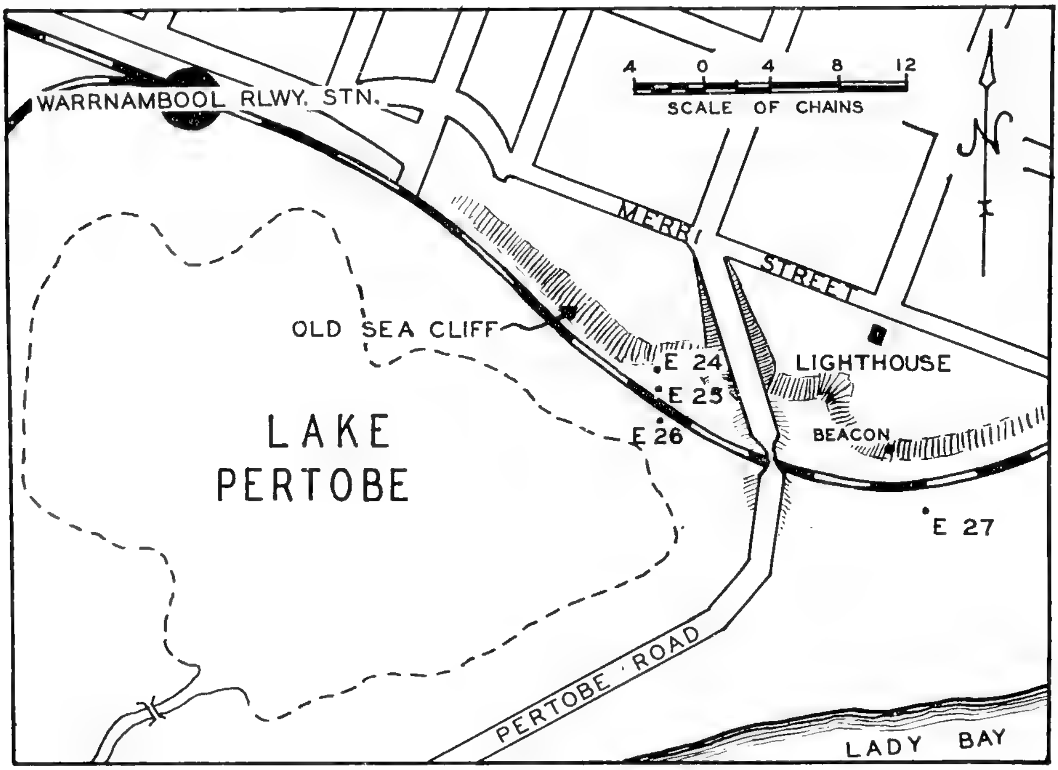

Fig. 14

Map of Lake Pertobe area, Warrnambool, showing sites of excavations 24 to 27.

auger holes is to be attributed to storm waves washing in the former. Mr. Henri Worland, former Town Clerk of Warrnambool and a local historian, kindly allowed me to view old photographs showing the sea washing over the beach at Lady Bay, across Pertobe Road, and into Lake Pertobe. The beach improvements and the introduction of marram grass at the beginning of this century have now caused an effective barrier to be raised against the sea.

In interpreting the Cannon Hill and Lighthouse sections, the following suggestions are put forward:

I. When the sea was a few feet higher than at present (later than both the 25-foot and 10-foot levels), a platform was cut in

the calcareous aeolianite below Cannon Hill, the sea then being where Lake Pertobe is now.

II. When the sea withdrew, red (oxidized) sandy soil formed on the former shore platform. It is very immature, shallow, and thins out rapidly seawards, so could not have had a long time to form. Under present conditions it would be impossible for such a soil to form in this situation, as marine and/or swamp waters would cover it. It appears to the writer that the sea went lower than it is at present, allowing the soil to develop from loose sand blown against the old sea-cliff, then as the sea came up, swampy conditions were generated. The succession in time of red, grey, then black deposits, and their respective faunas and floras, indicate increasing carbon content, and increasing conditions of chemical reduction as against oxidation.

III. The deposition of the tuff is associated with the present cycle of deposition in Lake Pertobe, in the same way as the tuff is associated with the present cycle of deposition of black clay in the Tower Hill Marsh. Although freshly-deposited volcanic ash is the most easily eroded of deposits, it has not been washed away from the old sea cliff at Cannon Hill and below the Lighthouse, proving that at the time of eruption of Tower Hill the sea was approximately where it is now. The deposition of the ash by the wind against the old sea cliff is therefore a very recent event indeed. Dr. A. W. Beasley, the National Museum Mineralogist, has confirmed the field determination of the material as volcanic ash (slide E538).

(d) *Koroit Beach Section.* (Text-figure 15; also Gill 1951*a*, plate O.) The area concerned is underlain by the tuff and lapilli, with occasional larger ejectamenta, from the nearby Tower Hill caldera. The ejectamenta constitute the shore platform. In fine weather the platform is mostly covered with sand, but in storm weather it is swept clean. The surveyed section shown in text-figure 15 is based on the level of the tuff platform near its outer edge (approximately low-water), no other datum being available for miles. The section line runs north-south at right angles to the shore, parallel to Gorman's Lane (which provides access to the beach) and about three-quarters of a chain east of its east fence-line.

Excavation 28. A spade hole four feet deep was dug in the yellow calcareous sand to make sure that the beach ridges of blocks of tuff and lapilli were two separate ridges. Since then wind scour has provided conclusive evidence that the beach ridge being formed at present is well separated from the fossil one further inland (see text-figure 15).

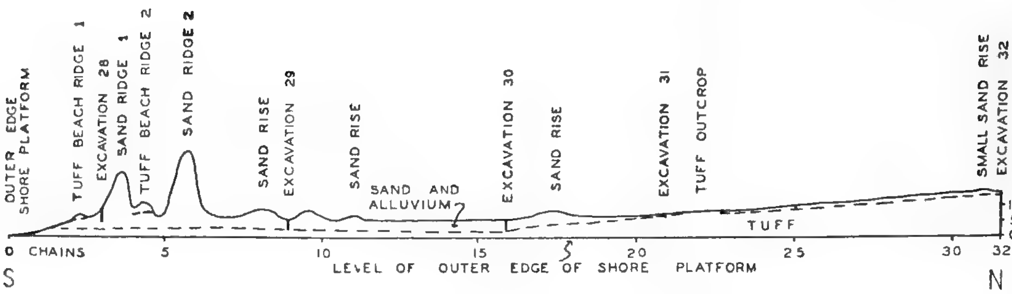

FIG. 15

Surveyed section on a north-south line at Koroit Beach, near the Tower Hill volcano, between Warrnambool and Port Fairy.

Excavation 29. Beside a sand-rise three feet high, an auger hole was sunk in a hollow through 4 ft. 2 in. of swamp deposits, finishing on tuff.

Excavation 30. Spade hole in a swampy depression about two feet below the surrounding terrain penetrated one foot of swamp deposits, finishing on tuff.

Excavation 31. Spade hole in a swampy depression about two feet below the surrounding terrain penetrated only superficial swamp deposits. Tuff outcrops in side of depression.

Excavation 32. Spade hole showed six inches of soil on tuff. In places over this section line are small sand rises varying from one to four feet high. The tuff platform shown by this section at about two feet above the present one, in addition to the repeated sand ridges and beach ridges of tuff blocks probably signify an emergence of a couple of feet. No reason was found for interpreting this emergence tectonically as a result of the local vulcanism, although it is difficult to trace such small movements. The dips and faults round the caldera have been mapped, and all appear to be limited to the caldera rim. It has been shown that the tuff from Tower Hill is later than the 25-foot and 10-foot platforms, and later than a platform five feet above low-water at Cannon Hill. If the two-foot platform at Koroit Beach is of the same age as the two-foot platform in Western Australia, then it is of the order of 1,000 years old, according to the calculations of Teichert (1947) and Fairbridge (1947*d*).

2. *Evidence from Radiocarbon Analysis*

Charcoal from the aboriginal kitchen midden on the Koroit Beach was sent to Professor W. F. Libby through the kind cooperation of Professor Hallam L. Movius Jnr. The sample was from the site shown in the photograph constituting plate O in Gill 1951*a*. The carbon-14 count gave an age of 538±200 years.

The midden is associated with a soil layer underlain only by sand and then the tuff. Later middens occur on the sand ridges themselves, e.g. immediately opposite the end of Gorman's Lane, and aborigines were still visiting the beach when white people arrived in the Country.

3. *Evidence from Stratigraphy*

The Cannon Hill and Koroit Beach sections show that the deposits on top of the tuff are comparatively thin and very recent. In numerous drain sections in the Tower Hill Marsh, one to six feet of black alluvium (like that seen in the Moyne River section) can be observed overlying the tuff. The tuff is associated with the formation at present in process of deposition.

4. *Evidence from Pedology*

Professor G. W. Leeper kindly examined a number of the fossil and extant soils in the Warrnambool area for me. On the top of the Miocene marine limestone and immediately under the tuff on the south side of the Tower Hill caldera is a fossil *terra rossa*. On the top of the tuff is a very immature loamy soil. Although the soil on the volcanic cinders (as seen in the quarry on the north side of the central cone complex) is rocky and immature, there is a band of re-deposited lime under the soil. With a view to ascertaining if this were due to the presence of comminuted limestone bedrock in the ejectamenta, samples of cinders from Mt. Leura, Mt. Noorat, and Tower Hill were treated with acid, and were found to lose 3%, 4% and 16% dry weight respectively. The soils on the Tower Hill tuff have a negligible quantity (if any) of buckshot gravel, thus contrasting with older tuffs such as those at Camperdown on which there is a well-developed podsol with buckshot. The richness of the Tower Hill soil is due to its youth. The pedological evidence thus indicates a very recent age for the Tower Hill tuff.

5. *Evidence from Physiography*

The Tower Hill Tuff follows the present contour of the country, but so also does the Hampden Tuff which is older. That the Merri River has not yet cut through the tuff all along its course, and that the ash spread is orientated to the present prevailing wind direction (Gill 1950*a*) are indications of a recent age. The fault scarp of the Tower Hill caldera is very sharp, and the amount of talus gathered at the bottom contrasts with the older calderas of Mt. Leura (Plate 3, figs. 3-4), Lake Bullenmerri, and Lake Gnotuk, where there is quite a lot of differential weathering, and in places of talus accumulation.

In review of the age of the Tower Hill Tuff, and so of the age of the Bushfield Axe and fossil bones, it can be concluded that it is very recent indeed. If the radiocarbon and eustatic sea-level datings are sound, the age is something like a thousand years.

4. Two Series of Middens

While studying the emerged shell beds of the Warrnambool and Port Fairy districts, a series of middens associated with the 25-foot shoreline was discovered. No middens were found between the very recent middens of the present coastline and those of the fossil shoreline, except along waterways, viz. the Hopkins River, the River Merri, the River Moyne and Goose Lagoon, 4½ miles west of Port Fairy—an ancient estuary. There are thus two separate series of middens, except where they are joined along waterways.

(a) *Coastal Middens.* These occur along sand dunes and aeolianite cliffs right on the present coast. Many have been destroyed of recent years by coastal erosion. The best known of this series of middens is that at Koroit Beach, Armstrong's Bay, north-west of Warrnambool (Kenyon 1912, Gill 1951*a*). Charcoal from this midden was sent to Professor W. F. Libby for radiocarbon analysis through the kind co-operation of Professor Hallam L. Movius Jnr. of Harvard University. The age given was 538±200 years, which is of the order anticipated (Libby 1951, Johnson 1951).

(b) *Inland Middens.* Examples of this series of sites are:

1. On the hill on the east side of Merri River, Dennington, above Moulden's sand quarry. This is near where the river enters extensive swamps behind large sand dunes. The site is well over a mile in a direct line from the present coast. Military Map, Port Fairy Sheet 1942, grid reference 377,694.

2. On top of aeolianite cliff, just north of Princes Highway, and one and a quarter miles east of Rosebrook, on west side of drain which cuts through aeolianite and underlying basalt. This site is over a mile in a direct line from the present coast. Same military sheet, grid reference 224,714.

3. A number of sites was found at Goose Lagoon, and from one of these charcoal was sent to Professor Libby for radiocarbon analysis. The site is on the northern slope of an aeolianite ridge, north of the Princes Highway, and on the east side of Goose Lagoon, near where a drain cuts through basalt and an emerged marine shell bed; it is three-quarters of a mile in a direct line from the present coast. Same military sheet, grid reference 127,674. The C14 dating was 1,177±175 years, which is much

younger than anticipated. The inland middens, like the coastal ones, consist of charcoal, marine shells of edible kinds and sizes, and flakes of flint. No proper implements were found in the inland middens, and none in the coastal middens except at Koroit Beach, where the writer has found a stone axe and numerous bone implements. The inland middens are in sites relative to the 25-foot shoreline comparable with the sites of recent middens relative to the extant shoreline, so much so that most of the localities were found by working on the analogy of the modern middens. It is generally believed that the aborigines did not carry the marine shellfish they collected any distance inland, but ate them near where they were found. For example, Dawson (1881, p. 19) says, "These immense mounds of shells being met with only near the sea, and nowhere in the interior, leads to the conclusion that the aborigines who fed on the mollusca and fish, never left the shore during the fishing season, and that, if they came from the interior, they never carried away any shellfish with them". MacPherson (1885, p. 55) noted "in some mounds about half a mile from the bay at Geelong there are fragments of shells which no doubt were brought from the neighbouring seashore". A few marine shells at a site is no criterion of an inland midden, because sea-shells were traded inland for use as implements and ornaments (see Dawson 1881, pp. 25, 78; Smyth 1878). If the middens are so young as the radiocarbon age given, then the shells must have been carried inland, but how did the aborigines come to select the 25-foot shoreline on which to have their feasts? As swamps often occupy the former bays, it might be thought that the aborigines chose the old shoreline because they found water in the adjacent swamps, but this could not apply to the middens along a waterway like the Hopkins River, and in some cases (as at Goose Lagoon) there was water nearer the coast. Further radiocarbon analyses are being arranged.

In Victoria, ancient middens now far from the sea have been reported by Dawson (1881, p. 19), Le Souef (1916), Kenyon (1927), and Keble (1928). In other States of Australia, Anderson (1890), Young (1926), Jardine (1928), and Voisey (1934) have reported comparable occurrences.

Acknowledgments

My thanks are due to Dr. D. E. Thomas for the loan of aerial photographs. The drafting of the maps and figures was done by my assistant, Mr. N. J. Shaw. In addition to the specific acknowledgments in the text, I am indebted to numerous residents of the areas described, who have provided help in many ways for the work in the field, especially Mr. P. Law Smith Senr., Mr. P. Law Smith Jnr., Mr. R. Hooper, Mr. John Manifold, and Mr. R. McAlpine.

Appendix I

Details of the *Colongulac Skeleton,* a fossil aborigine found in the loess dune at Lake Colongulac, Victoria.

Determinations by Professor S. Sunderland and Dr. L. J. Ray, Department of Anatomy, University of Melbourne.

P 15437 Femur Left
P 15438 Femur Right
P 15439 Sacrum
P 15440 Os Coxae Left
P 15441 Os Coxae Right
P 15442 Tibia Right
P 15443 Tibia Left
P 15444 Humerus Right
P 15445 Fibula Left
P 15446 Fibula (part missing) Right
P 15447 Ulna Left (incomplete)
P 15448 Radius Right
P 15449 Radius Left
P 15450 Ulna Right
P 15451 Trochlea Phalangis
P 15452 Os Pisiforme
P 15453 Patella Left
P 15454-62 Costae fragments
P 15463 Calcaneus Left
P 15464 Calcaneus Right
P 15465 Talus Left
P 15466 Talus Right
P 15467 Os Naviculare Left
P 15468 Os Cuneiforme Primus Right
P 15469 Os Metacarpale I Right
P 15470 Os Metatarsale IV Right
P 15471 Os Metatarsale I Left
P 15472 Os Metacarpale (base missing)
P 15473 Os Metacarpale I Left
P 15474 Phalanx Secunda
P 15475 Phalanx Prima
P 15476 Phalanx Prima
P 15477 Os Metacarpale III Right
P 15478 Phalanx Prima
P 15479 Phalanx Prima
P 15480 Phalanx Prima
P 15481 Os Metacarpale III Left
P 15482 Os Metacarpale II Left
P 15483 Phalanx Prima
P 15484 Os Metacarpale II Right
P 15485 Phalanx Prima
P 15486 Os Metatarsale II Right
P 15487 Phalanx Prima
P 15488 Os Metacarpale V Right
P 15489 Os Metacarpale V Left
P 15490 Os Metacarpale IV Right
P 15491 Os Metacarpale I Right
P 15492 Phalanx Tertia
P 15493 ,, ,,
P 15494 ,, ,,
P 15495 ,, ,,
P 15496 Phalanx Secunda
P 15497 Phalanx Prima
P 15498 Phalanx Secunda
P 15499 Phalanx Tertia
P 15500 Phalanx Secunda
P 15501 Phalanx Prima
P 15502 Phalanx Secunda
P 15503 Os Multangulum Minus (Trapezoid) Right
P 15504 Os Lunatum (Lunate) Right
P 15505 Os Naviculare Left
P 15506 Os Hamatum Left
P 15507 Os Metatarsal III Left
P 15508 Os Metatarsale V Left
P 15509 Fragmentum indet
P 15510 Vertebra Lumbalis I
P 15511 Vertebra Lumbalis III
P 15512 Vertebra Lumbalis IV (laminae of)
P 15513 Vertebra Cervicalis
P 15514 Vertebra Cervicalis VII
P 15515 Vertebra Cervicalis
P 15516
P 15517 Fragmentum indet.
P 15518 Os Cuboideum
P 15519 Os Cuneiforme Primum Right
P 15520 Os Capitatum Left
P 15521 Os Cuneiforme Tertium Left
P 15522 Os Cuneiforme Secondum Left
P 15523 Fragmentum indet.
P 15524 Fragmentum indet.
P 15525 Os Capitatum Right
P 15526 Dentis Incisivus
P 15527 Dentis
P 15528 Dentis

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DESCRIPTION OF PLATES

Plate I

Figure 1. Lake Colongulac seen from Mt. Leura, with other volcanoes in the distance.

Figure 2. Lake Colongulac, looking towards Mt. Leura from the point at the north end of the lake. In the middle distance, in front of Mt. Leura, is "Chocolyn".

PLATE II

Figure 3. The central cone complex of the Mt. Leura nested caldera. View looking north from the S.W. corner of the caldera. Figure standing on grey bedded tuff.

Figure 4. Same vicinity, looking south to show the somewhat eroded rim of grey bedded tuff and lapilli.

PLATE III

Figure 5. Lake Colongulac, east shore, looking N.E. from the mouth of Chocolyn Creek. Photograph taken at time of very low summer level. Note the cliffs cut in the Colongulac Loess. The Colongulac Skeleton came from the cliff at the extreme right of the photograph.

Figure 6. Mouth of Chocolyn Creek, looking upstream, showing the high level alluvium, and the incised meanders.

PLATE IV

Figure 7. The Colongulac Skeleton *in situ* after excavation but before removal from the Colongulac Loess.

Figure 8. Soil pipes in the south wall of the large quarry on the north side of the Princes Highway, near Mt. Leura (E 13 on text-figure 1).

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PLEISTOCENE FORAMINIFERA FROM PORT FAIRY, WESTERN VICTORIA

By A. C. Collins

Plate 1

SUMMARY

Shell sands of Pleistocene age from the environs of Port Fairy, Victoria, contain foraminiferal assemblages which are similar in most respects to those of present Victorian beaches, but include a small tropical element indicating warmer-water conditions. One set of samples contains pelagic and deeper-water forms indicating deposition on an open ocean beach, the other has a limited assemblage suggesting lagoonal conditions. One hundred and twenty-six species are listed, of which four are described as new, the most interesting being a new species of the genus *Fabularia,* which places the upper limit of geological range of this genus in the Pleistocene instead of the Lower Pliocene as hitherto known.

DESCRIPTION OF SAMPLES AND THEIR FORAMINIFERAL CONTENTS

Several samples of marine fossil material collected in the vicinity of Port Fairy, Western Victoria, were entrusted to the author for study by Mr. E. D. Gill, Palaeontologist, National Museum of Victoria. On examination they proved to contain an interesting foraminiferal fauna which throws some light on the climatic and ecological conditions prevailing at the time of their deposition. The author is glad to acknowledge the assistance rendered by Mr. Noel J. Shaw of the Museum staff, who selected many of the specimens here recorded, including the first-recognized specimen of the warm-water indicator *Amphisorus hemprichii.* The determinations of calcium carbonate were made by Mr. W. H. Edwards of the Chemistry Department, Gordon Institute of Technology, Geelong, to whom the author is also indebted for assistance.

The samples studied may be divided by their foraminiferal content into two groups, indicating different ecological conditions, as follows:

GROUP 1

Four samples of loose or consolidated shell sand from the following localities, collected by E. D. Gill, and a fifth sample collected by the author. They are described in detail below:

Sample 1. "Drain on north boundary of Port Fairy (excavated material)." A fine brownish calcareous sand containing molluscan and bryozoan débris, sponge spicules, and a rich foraminiferal assemblage. After treatment with cold dilute hydrochloric acid a residue of 25·5% was left, composed largely of angular grains of clear quartz and reddish-brown nodules, presumably iron oxide.

Sample 2. "Inland side of ridge on which Princes Highway runs, between Toolong Road and Glaxo Factory, and on both sides of next ridge inland for same distance including railway cutting at 185 miles." A fine even-grained light-coloured calcareous sand containing a foraminiferal assemblage similar to that of Sample 1, but not so rich in species. A residue of 28·2% was left after treatment with acid, consisting mainly of clear angular quartz grains and sponge spicules.

Sample 3. "Cliff on south bank of Moyne River ½-mile E.N.E. of Rosebrook Bridge." A fawn-coloured calcareous sand, fine in texture but partly cemented into irregular nodules. The uncemented material was similar in nature to Sample 2, 24% residue being left after treatment with acid.

Sample 4. "Port Fairy military map reference 216717. Shells in dune sand and consolidated limestone." This material was completely cemented and rather more calcareous in composition than the other samples, 16% of residue being left after acid treatment. Examination of scrapings indicated that the foraminiferal assemblage was generally similar to the other samples and no further examination was made.

Sample 5. Coarse unconsolidated shell-grit immediately below travertine layer in bank of drain on north boundary of Port Fairy, map reference 176678. This material was collected by the author. The finer fractions, consisting of a coarse shell-sand, almost entirely calcareous, produced many specimens of the larger miliolids, discorbines, etc. (Same locality as Sample 1.)

Generally speaking, the assemblages found in these five samples show marked resemblances to one another, the variations being only such as are found in different sections of a recent beach, due to varying conditions of deposition. As these differences appear to be due to such local variations, having no climatic, ecological or age significance, results have been combined in a single faunal list below. Type slides of each locality studied have, however, been deposited at the National Museum.

As with most beach collections they represent a thanatocoenosis, containing both shallow-water species and current-borne pelagic and deeper-water species. The faunule as a whole is substantially similar to that of ocean beach deposits on the Victorian coast, with the addition of a small but definite shallow-water tropical element. The pelagic species found are those which Wiseman and Ovey (1951) have shown to be warm-temperate or warm-water forms. Since the same species are found in recent beach deposits in the same area, no definite evidence of climatic change is given, but warmer conditions are not contra-indicated.

The species *Haddonia* cf. *minor* Chapman and *Amphisorus hemprichii* Ehrenberg, on the other hand, are strong evidence of warmer conditions, since their present habitat is in coral reef areas of the tropics. *Peneroplis pertusus* (Forskål) and *Discorbis*

mira Cushman are also warm-water forms, by the evidence of their general distribution, though *P. pertusus* has been recorded once from the Victorian coast (Chapman 1907) and *D. mira* from Glenelg, South Australia (Parr 1943). These warm-water indicating species were comparatively rare in the samples. In the case of such species as *Amphisorus hemprichii* and *Peneroplis pertusus* which in their normal habitat usually occur in great profusion, this comparative rarity suggests that they were close to the southern limit of their range.

Howchin (1923, 1935) records *Marginopora vertebralis* (as *Orbitolites complanata*) and *?Amphisorus hemprichii* (as *Orbitolites duplex*) from the Pleistocene of the Adelaide area. The evidence of the present work is consistent with this record, and indicates a somewhat more temperate climate under the influence of open oceanic exposure and some 3° more south latitude.

The following list of species is recorded from the samples of Group 1.

**Textularia pseudogramen* Chapman and Parr.
**Gaudryina (Pseudogaudryina) hastata* Parr.
**Clavulina difformis* Brady.
**Quinqueloculina baragwanathi* Parr.
**Q. bradyana* Cushman.
**Q. costata* d'Orbigny.
**Q. lamarckiana* d'Orbigny.
Q. moynensis sp. nov.
**Q. subpolygona* Parr.
**Massilina lapidigera* (Howchin and Parr).
**Spiroloculina angusteoralis* Parr.
**S. antillarum* d'Orbigny.
**S. disparilis* Terquem.
**Sigmoilina australis* (Parr).
**Triloculina circularis* Bornemann, var. *sublineata* (Brady).
**T. labiosa* d'Orbigny.
**T. labiosa d'Orbigny,* var. *schauinslandi* (Rhumbler).
**T.* sp. cf. *oblonga* (Montagu).
**T. subrotunda* (Montagu).
**T. tricarinata* d'Orbigny.
**T. trigonula* (Lamarck).
**T. striatotrigonula* Parker and Jones.
**Pyrgo depressa* (d'Orbigny).
Biloculinella globula (Bornemann).
Fabularia lata sp. nov.
**Ophthalmidium circularis* (Chapman).
Planispirinella tenuis sp. nov.
Nubecularia lucifuga Defrance.
**Parrina bradyi* (Millett).
Haddonia sp. cf. *minor* Chapman.
**Dentalina mutsui* Hada.
**Amphicoryne scalaris* (Batsch).
**Vaginulina vertebralis* Parr.
**Lagena distoma-margaritifera* Parker and Jones.
**L. distoma-margaritifera* P. and J., var. *victoriensis* Parr.
**L. gracillima* (Seguenza).
**L. acuticosta* Reuss, var. *ramulosa* Chapman.
**L. semistriata* Williamson.
L. spiralis Brady.
**L. striata* (d'Orbigny).
**L. sulcata* (Walker and Jacob).
**Oolina ampulla-distoma* (Rymer Jones).
O. costata (Williamson).
**O. globosa* (Montagu).
**O. hexagona* (Williamson).
**O. squamosa* (Montagu).
**O. tasmanica* Parr.
**O. variata* (Brady).
**Fissurina clathrata* (Brady).
**F. lacunata* (Burrows and Holland).
F. marginato-perforata (Seguenza).
**F. orbignyana* (Seguenza), var.
**Guttulina regina* (Brady).

**Globulina gibba* d'Orbigny, var. *globosa* Münster.
**Sigmoidella kagaensis* Cushman and Ozawa.
**Elphidium argenteum* Parr.
E. crispum (Linne).
**E. macellum* (Fichtel and Moll).
E. rotatum Howchin and Parr.
**Parrellina verriculata* (Brady).
**Notorotalia clathrata* (Brady).
**Peneroplis pertusus* (Forskål).
Amphisorus hemprichii Ehrenberg.
**Bolivinella folium* (Parker and Jones).
Buliminella gracilis sp. nov.
**Bulimina marginata* d'Orbigny.
**Bolivina compacta* Sidebottom.
**B. pseudoplicata* Heron-Allen and Earland.
**B. robusta* Brady.
**B. subreticulata* Parr.
B. subtenuis Cushman.
**Rectobolivina digitata* Parr.
**Uvigerina bassensis* Parr.
**Siphogenerina raphanus* (Parker and Jones).
**Angulogerina angulosa* (Williamson).
Trifarina bradyi Cushman.
**Spirillina vivipara* Ehrenberg.
**S. denticulata* Brady.
**S. inaequalis* Brady.
**Turrispirillina depressa* Parr.
**Patellina corrugata* Williamson.
**Patellinella inconspicua* (Brady).
**Annulopatellina annularis* (Parker and Jones).
**Discorbis australensis* Heron-Allen and Earland.
**D. australis* Parr.
**D. dimidiatus* (Parker and Jones).
D. dimidiatus (P. and J.), var. *acervulinoides* Parr.
**D. haliotis* Heron-Allen and Earland.
D. mira Cushman.
**D. orbicularis* (Terquem).
**D. pulvinatus* (Brady).
**Discorbinella biconcava* (Jones and Parker).
**D. disparilis* (Heron-Allen and Earland).
**D. planoconcava* (Chapman, Parr and Collins).
**Heronallenia translucens* Parr.
**Valvulineria collinsi* (Parr).
**Stomatorbina concentrica* (Parker and Jones).
Mississipina pacifica Parr.
**Streblus beccarii* (Linne).
**Siphonina tubulosa* Cushman.
**Baggina phillipinensis* Cushman.
**Tretomphalus concinnus* (Brady).
**T. planus* Cushman.
**Cassulinoides chapmani* Parr.
**Ehrenbergina pacifica* Cushman, var. *aspinosa* Parr.
**Globigerina bulloides* d'Orbigny.
**Globigerinoides conglobata* (d'Orbigny).
**G. ruber* (d'Orbigny)
**Orbulina universa* d'Orbigny.
**Globorotalia crassula* Cushman and Stewart.
**G. hirsuta* (d'Orbigny).
**G. truncatulinoides* (d'Orbigny).
**Cibicides lobatulus* (Walker and Jacob).
**C. pseudoungerianus* (Cushman).
**C. subhaidingeri* Parr.
Vagocibides sp. cf. *maoria* Finlay.
**Dyocibicides biserialis* Cushman and Valentine.
**D. laevis* Parr.
Cyclocibicides vermiculatus (d'Orbigny).
**Planorbulina mediterranensis* d'Orbigny.
**Acervulina inhaerens* Schultze.
**Gypsina vesicularis* (Parker and Jones).

Species marked * have been previously recorded from the Victorian coastline or Bass Strait.

Group 2

One sample only. "Right bank of Moyne River, 0·6 mile slightly east of north of Rosebrook, Western Victoria." A dark grey coherent material washing down to a calcareous sand composed of

comminuted shells, etc., with some angular quartz grains and small aggregations of what appears to be carbonaceous material.

The foraminiferal fauna is scanty but ecologically interesting. The dominant forms are *Streblus beccarii* (L.), *Elphidium crispum* (L.), and *Discorbis dimidiatus* (P. and J.). Besides these there is a scattering of species which with one or two exceptions occur in the samples of the previous group.

This assemblage is also a thanatocoenosis. The specimens of *Streblus* are perfect and comparable with recent tests, whereas the tests of all other species are more or less eroded, with the ornament and sharp edges smoothed off in a manner suggesting wind-polishing rather than wave action. From this it may be deduced that the conditions of deposition were those of a brackish-water lagoon in which *Streblus* would flourish, cut off from the sea by a sand-bar from which tests of the less adaptable marine species were derived by wind and possibly wave action. The assemblage of species probably derived in this way is closely related to those found in the samples of Group 1, but is not identical and probably represents a different facies. There is a complete and rather surprising absence of miliolid genera for which no explanation has been found.

Some indication is given of climatic conditions by the presence of a worn specimen referable to *Operculina*, a genus not represented in the samples of Group 1. Its presence is, however, consistent with the records of *Amphisorus* and *Haddonia*, and it provides further evidence of warm-water conditions. Two badly-worn examples of a spinous rotalid of the *R. calcar* group were found in this sample. These forms also have a predominantly warm-water distribution.

The following list of species is recorded from the above sample:

**Textularia sagittula* Defrance.
**Lagena acuticosta* Reuss, var. *ramulosa* Chapman.
**Sigmoidella kagaensis* Cushman and Ozawa.
**Guttulina regina* (Brady).
Elphidium crispum (Linne).
**E. sculpturatum* Cushman.
E. rotatum Howchin and Parr.
**Bulimina marginata* d'Orbigny.
**Bolivina pseudoplicata* Heron-Allen and Earland.
**Uvigerina bassensis* Parr.
**Siphogenerina raphanus* (Parker and Jones).
**Discorbis dimidiatus* (Parker and Jones).
**Discorbinella planoconcava* (Chapman, Parr and Collins).
**Streblus beccarii* (Linne).
Rotalia sp. (calcar group).
**Globigerina bulloides* d'Orbigny.
**Gypsina vesicularis* (Parker and Jones).
Operculina sp.

Species marked * have been previously recorded from the Victorian coastline or Bass Strait.

NOTES ON NEW AND INTERESTING SPECIES

Family MILIOLIDAE

Genus QUINQELOCULINA d'Orbigny 1826

Quinquelocluina moynensis sp. nov.

Pl. I, figs. 1a-c

Test small, subquadrate, about twice as long as wide, quinqueloculine, chambers smooth with a rounded limbate keel, aperture elliptical with a small simple tooth at the end of a short blunt neck. Dimensions of holotype: length 0·55 mm., width 0·29 mm., thickness 0·19 mm., from sample 2, where it is not uncommon. Holotype in National Museum of Victoria, Reg. No. P 15666.

This small species appears to have no close relation to any described form,· its particular features being the subquadrate outline and strongly keeled chambers. It has not been met with in recent material. The specific name relates to the Moyne River, which runs through the general area of these collections.

Genus FABULARIA Defrance 1820

Fabularia lata sp. nov.

Pl. I, figs. 2a, b; 3a, b; 4a, b

Test oval to subcircular in outline, with ends somewhat truncate, compressed at right angles to the plane of coiling, margins rounded. Aperture narrow, extending over the full width of the apertural end and consisting of a double row of pores with limbate margins. Plan of growth quinqueloculine in earliest stages, then triloculine, and finally biloculine, at which stage the chambers become subdivided by meridional partitions which end short of the aperture. Fig. 3 shows a sectioned specimen having a proloculum 0·05 mm. in diameter, then a quinqueloculine and triloculine stage of 6 chambers followed by a biloculine stage of 11 chambers, making 17 in all. Fig. 4, a section of another specimen, has a proloculum 0·025 mm. in diameter, then an irregularly quinqueloculine (or sigmoid) and triloculine stage of 9 chambers followed by a biloculine stage of 13 chambers making 22 in all. These possibly represent respectively the megalospheric and microspheric forms of the species.

Dimensions of holotype: length 2·16 mm., width 2·16 mm., thickness 1·0 mm., from sample 1. It is common in the coarser sediments of sample 5. Holotype in the National Museum of

Victoria, Reg. No. P 15667. Paratypes (2) Reg. Nos. P 15668 (fig. 3) and P 15669 (fig. 4).

This species may be compared with *F. howchini* Schlumberger, described from the Lower Pliocene of Hamilton, Victoria; from which it differs in its subcircular, truncate and compressed test and by its long narrow aperture. The present record is of particular interest in that it extends the geological range of the genus, previously known from the Eocene of Europe, North Africa and America and the Lower Pliocene of Australia, to the Pleistocene, in company with an assemblage of species of recent character. The two Australian records of the genus are from localities in the same geographical area, some fifty miles apart, indicating the persistence of the genus in this area almost to recent times.

It may be noticed that the compressed form of the test takes what appears to be an evolutionary trend in the genus a step further, Eocene species being compressed laterally, the Australian Pliocene species subfusiform and the present species compressed frontally. Immature specimens (judged by their size) of *F. lata* tend to be comparatively more slender and fusiform, the compressed and laterally expanded form being taken on in the last few chambers.

Family OPHTHALMIDIIDAE
Subfamily OPHTHALMIDIINAE
Genus PLANISPIRINELLA Wiesner 1931
Planispirinella tenuis sp. nov.

Pl. I, fig. 5

Test minute, porcellaneous, thin, with a rounded proloculum followed by an undivided planispiral tube of about 3 convolutions, gradually increasing in diameter, then becoming septate, the first chamber taking up about $\frac{2}{3}$ of a convolution and the next two $\frac{1}{2}$ and $\frac{1}{4}$ respectively. Both faces are slightly concave and sutures are depressed. Chambers are subcircular in section, forming a rounded periphery, with the aperture formed by the slightly constricted open end of the last chamber. Diameter of holotype 0·17 mm. Rare in sample 1. Holotype in National Museum of Victoria, Reg. No. P 15665.

This minute species differs from *P. exigua* (Brady) in its regular spiral outline, rounded periphery and concave faces, the early chambers being distinct and not obscured by shell growth.

Family PLACOPSILINIDAE

Subfamily POLYPHRAGMINAE

Genus Haddonia Chapman 1898

Haddonia sp. cf. *minor* Chapman

Pl. I, fig. 6

Cf. *Haddonia minor* Chapman 1902, p. 384, pl. 36, figs. 1, 2.

Four specimens referable to this genus were found. In form they resemble *H. torresiensis* Chapman, but their small size, *circa* 2 mm., precludes their reference to this species and they are placed tentatively in Chapman's second species *H. minor*. The specimens differ from Chapman's figures in their lower and more regular chambers and the apertural characteristics which are closer to those of *H. torresiensis,* and it is possible that they represent a new species. Two of the specimens are conjoined, one having evidently grown on the other as a surface of attachment. The genus has a generally tropical distribution and has not hitherto been recorded from southern Australian localities. From samples 1 and 5, the figured specimen being from sample 1.

Family NONIONIDAE

Genus Elphidium Montfort 1808

Elphidium rotatum Howchin and Parr

Elphidium rotatum Howchin and Parr 1938, p. 299, pl. xvii, figs. 1, 2, 4.

The type of this species came from recent shoresands at Kingston, South Australia, and it is recorded from the Upper Pliocene of the Adelaide area. It has not hitherto been recorded from Victoria. Rare in sample 5 of Group 1, and in Group 2.

Family PENEROPLIDAE

Subfamily SPIROLININAE

Genus Peneroplis Montfort 1808

Peneroplis pertusus (Forskål)

Nautilus pertusus Forskål 1775, p. 125, No. 65.
Peneroplis pertusus Brady 1884, p. 204, pl. xiii, figs. 16, 17.
Chapman 1907, p. 126.

Two specimens of this well-known warm-water form were found. It has been recorded from Point Nepean, Victoria, by

Chapman; and the author has also found it in Victorian shore-sand. It is a common species in Northern Australian waters but strangely enough has not been recorded from Gulf St. Vincent, South Australia, where a related species, *P. planatus* (Fichtel and Moll) is abundant.

Subfamily ORBITOLITINAE

Genus AMPHISORUS Ehrenberg 1840

Amphisorus hemprichii Ehrenberg

Amphisorus hemprichii Ehr. 1838, p. 134, pl. iii, fig. 3.
? *Orbitolites duplex* Carpenter, Howchin 1935, p. 69.
A. hemprichii Howchin and Parr 1938, p. 301, pl. xix, fig. 7.

This is probably the form recorded by Howchin (as *Orbitolites duplex*) from the Pleistocene of the Adelaide plain. It is further recorded by Howchin and Parr from the Upper Pliocene of Adelaide and is a common species in the warm waters of Northern Australia. It does not appear to have been recorded from Southern Australia as a recent form, and its presence in the material examined is a fairly good indication of warmer water conditions than at present. Not uncommon in the coarse grit of sample 5, rare in the other samples of Group 1.

Family BULIMINIDAE

Subfamily VIRGULININAE

Genus BOLIVINA d'Orbigny 1839

Bolivina subtenuis Cushman

Pl. I, fig. 7.

Bolivina tenuis Brady, (*non* Marsson) 1881, p. 57, 1884, p. 419, pl. 52, fig. 29.
B. subtenuis Cushman, 1936, p. 57, pl. 8, fig. 10.

Examples of a peculiar bolivine of oval outline, having long curved chambers tending to become sharply recurved at the inner end, giving the appearance of subdivision, were fairly common in the finer fractions of the Group 1 samples. The aperture is slit-like with radiating lines extending over the end of the last chamber and placed well to one side of the test. In many specimens the shell wall in the vicinity of the aperture is broken or resorbed, giving the appearance of a roughly oval aperture as figured by Cushman, but in perfect specimens the aperture is obscure and defined by the radial pattern of ornament, as in Brady's fig. 29.

The specimens are referable to the above species, which appears to have no closely related forms. Its distribution has hitherto been confined to the tropical Indo-Pacific. The figured specimen is from sample 1.

Subfamily TURRILININAE

Genus Buliminella Cushman 1911

Buliminella gracilis sp. nov.

Pl. I, figs. 8a, b.

Test elongate, tapering, subcylindrical, rounded at initial end and obliquely truncate at the oral end. Chambers numerous and narrow, arranged in a close spiral of up to 4 convolutions. Sutures broadly limbate, spiral suture distinct and depressed. Surface smooth and finely punctate. Aperture small, obscure, in centre of depressed apertural face, with radial striae on the face of the last chamber. Dimensions of holotype: length 0·49 mm., width 0·14 mm., from sample 1. Not uncommon in the finer fractions of Group 1 samples. Holotype in National Museum of Victoria, Reg. No. P 15664.

The subcylindrical form and oblique truncate oral end of this species suggest relationship with *Buliminoides,* but it lacks the development of costae parallel or nearly so to the direction of spiral growth. It differs from *Elongobula* in the regular spiral sequence of chambers, more typical of *Buliminella.*

Its relationship appears to be with forms such as *B. multicamera* Cushman and Parker; described from the Pliocene of Castel Arquato, Italy, and recorded as a recent form from the Mediterranean and Indo-Pacific. It differs from that species in its slenderness and heavily limbate sutures. Some specimens show an irregular variation in the length of chambers, giving the effect of a tendency toward biseriality as described for *B. multicamera.* In the present species, however, this irregularity occurs at random and does not suggest an evolutionary tendency. A closely related form occurs in the recent shoresands of the Victorian coast.

Family ROTALIIDAE

Subfamily TURRISPIRILLININAE

Genus Turrispirillina Cushman 1927

Turrispirillina depressa Parr

Turrispirillina depressa Parr, 1950, p. 351, pl. xiii, figs. 17 and 18.

Described by Parr from off Tasmania, this is a further interesting occurrence of a seldom-recorded genus. One specimen was found, closely similar to Parr's fig. 18.

Subfamily DISCORBINAE

Genus Discorbis Lamarck 1804

Discorbis mira Cushman

Discorbis turbo Brady (*non d'Orbigny*) 1884, p. 142, pl. 87, figs. 8a-c.
D. mira Cushman 1922, p. 39, pl. 6, figs. 10 and 11.

Recorded by Parr (1943) from recent shoresands at Glenelg, South Australia. Chapman's record of *D. turbo* (1907, p. 134) may refer to this species, otherwise it has not hitherto been recorded from Victoria. From its recorded distribution it is evidently a warm-water form. It occurs in the Pliocene of southern Australia (*fide* Parr).

Subfamily SIPHONININAE

Genus Siphonina Reuss 1850

Siphonina tubulosa Cushman

Truncatulina reticulata Brady, (*non* Czjek), 1884, p. 669, pl. 96, figs. 5-7.
Siphonina tubulosa Cushman 1924, p. 40, pl. 13, figs. 1 and 2, 1927, p. 10, pl. 1, figs. 3a-c, 5a-c, Parr 1950, p. 362.

This species, recorded by Brady from Bass Strait, has not to my knowledge been recorded since from Victoria, though it has been found in the tropical Indo-Pacific, and off Tasmania.

Family ANOMALINIDAE

Subfamily CIBICIDINAE

Genus Vagocibicides Finlay 1939

Vagocibicides cf. *maoria* Finlay

Pl. I, figs. 9a-c.

Cf. *Vagocibicides maoria* Finlay, 1939, p. 236, pl. 29, figs. 146-151, 158.

One specimen, figured here, was found in sample 3. It appears to be fairly close to Finlay's species from the Tertiary of New Zealand. A similar form which may also be referable to this species has been found by the author in recent beach sands from Tidal River, Wilson's Promontory, Victoria.

This form appears to be derived from *Dyocibicides* by the gradual assumption of uniserial growth combined with the coming-together and fusion of the dorsal margins of the last chamber so that it becomes sub-globular. This fusion is shown in the figured specimen by the slightly depressed groove ending at the aperture.

More specimens are needed to establish the limits of variation of this form and it is therefore provisionally referred as above. The figured specimen is from sample 3.

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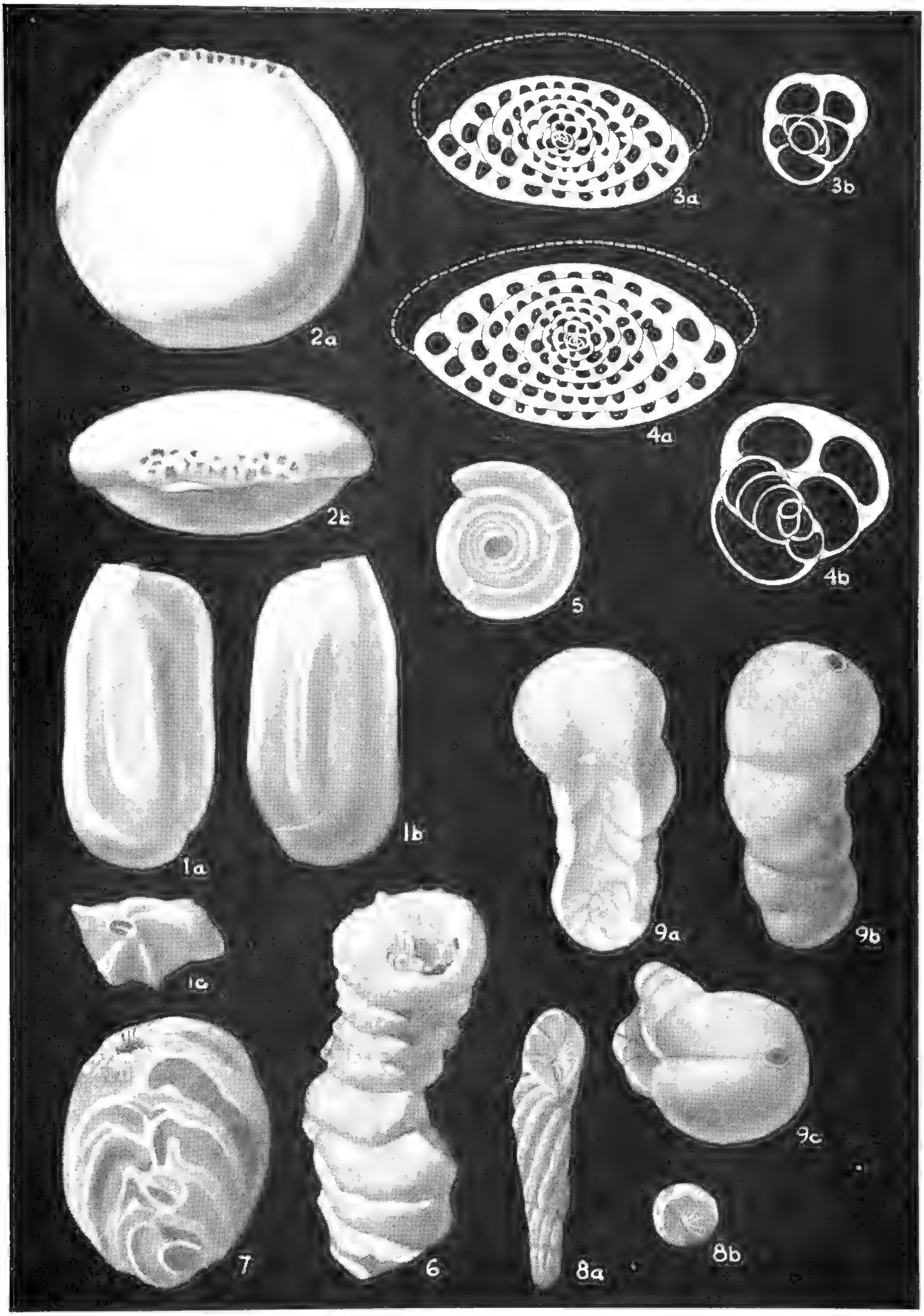
Explanation of Plate I

Fig. 1. *Quinqueloculina moynensis* sp. nov. Holotype, *a* and *b* side views, *c* oral view. x 80. P 15666.

Fig. 2. *Fabularia lata* sp. nov. Holotype. *a* side view, *b* oral view. x 20. P 15667.

Fig. 3. *F. lata* sp. nov. Paratype. *a* transverse section, x 20; *b* early chambers enlarged, x 80. P 15668.

Fig. 4. *F. lata* sp. nov. Paratype. *a* transverse section, x 20; *b* early chambers enlarged, x 80. P 15669.
Fig. 5. *Planispinella tenuis* sp. nov. Holotype. Side view. x 140. P 15665.
Fig. 6. *Haddonia* sp. cf. *minor* Chapman. x 30. P 15663.
Fig. 7. *Bolivina subtenuis* Cushman. x 80. P 15663.
Fig. 8. *Buliminella gracilis* sp. nov. Holotype. *a* side view, *b* oral view. x 80. P 15664.
Fig. 9. *Vagocibicides* sp. cf. *maoria* Finlay. *a* dorsal view, *b* ventral view, *c* oral view. x 80. P 15663.



3a
3b
2a
4a
2b
4b
5
1a
1b
9a
9b
1c
9c
7
6
8a
8b

MEM. NAT. MUS. MELBOURNE, 18, 1953.

RECORDS OF THE OCCURRENCE OF *BOTRYOCOCCUS BRAUNII*, *PEDIASTRUM* AND THE HYSTRICHOSPHAERIDEAE IN CAINOZOIC DEPOSITS OF AUSTRALIA

By Isabel C. Cookson, D.Sc.
University of Melbourne

Plates I-II

SUMMARY

Several occurrences of *Botryococcus braunii* in Australian deposits ranging from Tertiary to Quaternary have been recorded.

Pediastrum boryanum has been isolated from two Tertiary localities, one in Victoria and one in South Australia.

Eleven distinct types of the Hystrichosphaerideae, representing four genera known from European deposits, have been identified.

A new species, referred to *Cannosphaeropsis* O. Wetzel, has been described.

The palaeoecological importance of these microfossils and the distribution of the Hystrichosphaerideae have been considered.

INTRODUCTION

Botryococcus and the *Hystrichosphaerideae* have been known for some considerable time as fossil components of peats and older deposits in Europe and Britain, but neither they nor *Pediastrum* has previously been recorded from Australian Cainozoic strata.

Their occurrence in Australian beds of this period was first noted during a pollen analysis. They were found in residues which resulted from the treatment of certain Tertiary clays and sandstones with hydrofluoric acid followed either by Schultze's solution and alkali or chlorination-acetolysis mixtures. Since then new occurrences in widely separated beds of different ages have come to light. These discoveries, however, have been quite fortuitous and as such provide only limited information regarding the age and distribution of all three types of microfossils. Unfortunately a more detailed and systematic investigation is not possible at present. It has therefore been decided to record the findings as they stand in the hope that they may be of some palaeoecological and micropalaeontological interest.

(1) *Botryococcus braunii* Kützing
(Plate 1, figs. 1-6)

(i) *Historical Record*

So much has been written recently regarding the structure and geological occurrence of *Botryococcus braunii* that only brief reference to both aspects need be given here.

The structure of the living colonies and the individual cells of which they are composed has been exhaustively dealt with by Blackburn (1936) and Frémy and Dangeard (1938).

Temperley (1936) and Harris (1938) have both expressed considered opinions regarding the synonomy and geological history of *B. braunii,* and in 1944 Dulhunty discussed the origin of the Australian boghead or Kerosene Shale in New South Wales. As the result of these and other investigations, it is now generally believed that an alga identical with the living *B. braunii* has existed from the Ordovician onwards and was responsible for the production of localized deposits of boghead coal in various countries.

(ii) *Structure and Occurrence*

B. braunii is a cosmopolitan colonial alga which usually inhabits freshwater lakes and ponds. Sometimes, as in the lagoons of the Coorong along the south-eastern coast of South Australia (Dulhunty 1944) and in certain lakes in Russia, it lives in salt and brackish water.

The colonies are generally spherical or nearly so and vary in size according to the number of daughter colonies which remain attached to one another. This attachment is effected by means of definite strands as is shown in plate I, fig. 3.

The individual cells, themselves, are pear-shaped. Each lies in a thin cup-shaped thimble of cuticular nature which in turn is surrounded by a thick fatty cup open at the distal end. The cell in this region is covered by a cap composed of cellulose and pectic substances.

Cell divisions take place in longitudinal directions at right angles to one another. After a division, each daughter cell secretes a new thimble and cup within the parent wall. Thus the cells of a colony are primarily grouped in pairs and, as the number of cells and cell groups increases, a definite skeletal framework is gradually built up.

This framework is of a fatty nature and extremely resistant to decay. Very often it retains its original form in the fossil condition, empty cups in pairs or larger groups such as fours, sixes

or eights being clearly visible. It is the preservation of such features in colonies isolated from the various deposits, to be cited, that has permitted their identification with *B. braunii.*

The fossil colonies vary considerably in size from small individuals about 10μ in diameter to large compound groups with diameters of about 100μ. The length of the cells ranges from 5-15μ.

Different races of *Botryococcus* such as those distinguished by Blackburn (1936) have not been recognized.

(iii) *Cainozoic Distribution*

New South Wales:

Warlands Creek seven miles north-east from Murrundi. Clay and sandy wash beneath Tertiary basalt. Age: Probably Oligocene-Miocene. Portion of Dr. J. Dulhunty's coal sample 176—remaining fraction Nat. Mus. Melb. No. P 15584. *Botryococcus braunii* abundant. Pollen content low, a few winged pollen grains observed.

Victoria:

Lal Lal near Ballarat (Thomas and Baragwanath 1950). Geol. Surv. of Vic., bores 60 and 62. Carbonaceous clays. Age: ? Oligocene. Bore 60, at 69 ft., Geol. Surv. Vic. No. 11907. *Botryococcus* moderately abundant. Pollen content high, mainly winged grains of the Podocarpaceae. *Nothofagus* sp. *b* and *N.* sp. *c* observed (Cookson 1946).

Bore 60, at 67 ft., Geol. Surv. Vic. No. 11908. *Botryococcus* abundant. Pollen content high, includes *Araucariacites australis* varieties of winged podocarpaceous types and *Nothofagus* sp. *b*.

Bore 62, at 246 ft., Geol. Surv. Vic. No. 11909. *Botryococcus* sparse. Pollen content high, includes winged types and *Nothofagus* sp. *b, N.* sp. *c, N.* sp. *d,* and *N.* sp. *e.*

Anglesea. Coastal cliff near mouth of the Anglesea River. Black carbonaceous sandstone. Age: Oligocene (Singleton 1941, p. 13). *Botryococcus* sparse, pollen content high, includes *Araucariacites australis,* a number of distinct podocarpaceous types, *Nothofagus* sp. *b,* N. sp. *c,* N. sp. *f,* and several types of Hystrichosphaerids.

Werona, near Campbelltown. Carbonaceous clay under newer basalt. Age: Late Tertiary (Harris and Thomas 1948). Geol. Surv. Vic. No. 11906. *Botryococcus* moderately abundant. *Pediastrum* very infrequent. Pollen content very low.

Stony Creek Basin near Daylesford. Dark shale. Age: ?Middle Pliocene (Coulson 1950). Nat. Mus. Melb. No. P 15583. *Botryococcus* moderately abundant. Pollen content only moderate, several podocarpaceous types observed.

South Ecklin, 12 miles from Terang. Peat. Age: Quaternary. Geol. Surv. Vic. No. 11910. *Botryococcus* moderately abundant. Pollen content negligible. Unidentified, thick-walled, pointed hairs (plate I, fig. 18) moderately numerous.

Moyne River, right bank, 0·6 mile slightly E. of N. of Rosebrook Bridge; military map, Port Fairy sheet 1942, grid reference 202,719, Western Victoria. Clay resting on marine shell bed. Quaternary. Nat. Mus. Melb. No. P 15586. *Botryococcus* present but not abundant. Pollen content moderate; spheroidal cribellate pollen grains 29-39μ in diameter (average 33·5μ) are conspicuous (plate I, fig. 17). These have more than fifty pores and thus can be safely referred to the Chenopodiaceae (Faegri and Iverson, 1950, p. 147). Shells of *Hystrichosphaera furcata* moderately numerous.

South Australia:

Cootabarlow, east of Lake Frome. S.A. Dept. of Mines. Bore at 471-493 ft. Carbonaceous shale. Age: ?Early Tertiary. Nat. Mus. Vic. No. P 15585. *Botryococcus* very abundant accompanied by *Pediastrum.* Pollen grains rare.

Western Australia:

Shannon River, south coast Western Australia. Lignite. Age Tertiary. Geol. Dept. Univ. W.A. No. 40. *Botryococcus* abundant. Pollen content moderate.

(2) *Pediastrum boryanum* (Turp.) Menegh.
(Plate I, Figs. 7-11)

Only three references to the fossil occurrence of *Pediastrum* have been found. These are the report by Davis (1916) of its presence in the Eocene Green River Shales of U.S.A., the mention by Blackburn (1936) of well-preserved colonies in preparations of lake mud after treatment with 10% potash, and the record by Iversen (1936) of its occurrences as a secondary constituent in unweathered boulder-clay from North Jutland. In none of these cases were illustrations and descriptive notes of the fossil species provided.

Pediastrum is a cosmopolitan green alga frequently found amongst plankton in freshwater lakes and ponds. The colonies have the form of minute stellate plates composed of a single layer of regularly arranged cells four to one hundred and twenty-eight in number. The marginal cells of a colony differ from the internal cells in having one, two, or three more or less prominent processes.

Colonies agreeing with the general features of *Pediastrum* are associated in moderate numbers with *Botryococcus braunii* in the carbonaceous shale from the Cootabarlow bore at 471-493 ft. They are remarkably well preserved and even after the drastic action of Schulze's solution, several, almost entire, colonies have been seen. Fragmentary remains of *Pediastrum* occur very sparsely in the clay from Werona.

The colonies observed have had diameters ranging from 42-143μ (processes included) and have been composed of from eight (plate I, fig. 7) to approximately 60 cells (plate I, fig. 11). In them a central cell is usually evident around which the remaining cells are concentrically arranged. The width of the cells is from 13-18μ. Each marginal cell has two rather horn-like processes, 8-13μ long, with truncate ends. The cell walls are usually distinctly granular, but in the specimen shown in plate I, fig. 8, the surface appears to have been almost smooth.

The fossil colonies agree most closely with those of *P. boryanum* of the section *Diactinium* A. Br. (Lindau and Melchoir 1930, p. 149). In this species, as in the fossil, the individual cells are closely united and not separated by perforations as they are in *P. duplex* Meyers of the same section. There is further agreement as regards the paired marginal processes, the number of cells of which the colonies are composed and the granular nature of the cell walls. It is in view of this close similarity that the fossil *Pediastrum* has been identified with the living species *P. boryanum.* In this connection West's record (1909) of *B. boryanum* in the littoral algal flora of the Yan Yean Reservoir near Melbourne is of some interest.

3. *Hystrichosphaerideae*

General Account

The Hystrichosphaerideae comprise a variety of obscure unicellular marine microfossils of uncertain affinities. All consist of a more or less spherical or ovoid body or shell which is variously ornamented with branched or unbranched spine-like or tubular appendages. Their membranes are resistant to strong acids and remain in good condition after chlorination and acetolysis.

The microfossils included in this group have had a long geological history. They have been recorded from rocks as far back as the Upper Cambrian* and are of frequent occurrence in European marine strata from the Jurassic period onwards. Forms similar or very close to the Hystrichosphaerideae have been occa-

*A. Eisenack *Senckenbergiana* 32, p. 194.

sionally mentioned in present day plankton. (Deflandre, 1947, p. 13, Pastiels, 1948, p. 48).

The identity of the Hystrichosphaerids has been much discussed (Deflandre 1947, Pastiels 1948, etc.). Ehrenberg (1836) believed them to be the zygospore cases of *Xanthidium*, a living genus of the Desmidiaceae. Since then, they have been variously thought to be eggs of planktonic crustacea, cysts, radiolaria of the group Collosphaerida, remains of organisms related to the Dinoflagellates and spores.

In 1933 O. Wetzel removed Ehrenberg's species from *Xanthidium* to *Hystrichosphaera* and at the same time created other new genera and species. Subsequently Deflandre (1937) redefined the limits of Hystrichosphaera by including in it only those species in which the shells are subdivided into polygonal fields and equatorial plates. Those species with unsegmented membranes were classified as *Hystrichosphaeridium*.

The occurrence of the Hystrichosphaerideae in Australian Tertiary deposits demonstrates how widespread their past distribution must have been, although this is not surprising since they are members of the plankton. The age of the Australian deposits in which they have been located ranges from Oligocene to Quaternary. Several of the genera known from European horizons have been recognized. Both generic and specific determinations have, however, been hampered by lack of literature on the one hand (Wetzel's paper (1933) for example has not been seen) and by an insufficient number of examples of some of the types on the other. At a later date a more detailed investigation may be possible.

Australian Cainozoic Occurrences

Victoria:

Anglesea (see p. 109). Type locality of the Anglescan stage. Age: Oligocene. Hystrichosphaerids are associated with *Botryococcus* and a number of pollen types.

Gellibrand River. About ¾ mile south-east of Point Ronald, at the river mouth. Poorly fossiliferous carbonaceous sandy shale which is lithologically similar to the black sandstone at Anglesea (Baker 1944, 1953). Age: ?Oligocene. Several types of Hystrichosphaerids observed. Pollen content moderate, includes *Araucariacites australis* and a few podocarpaceous types. All references in this paper to the Gellibrand River allude to this locality.

Balcombe Bay. Type locality of the Balcombian series. (Singleton 1941, p. 27.) Grey shelly clay rich in foraminifera. Age:

Miocene. Several varieties of Hystrichosphaerids occur. Pollen content very low, includes *Araucariacites australis.*

Nelson Bore. Bore put down near the south-western end of the bridge over the Glenelg River at Nelson. Carbonaceous shaley layer in micaceous sandstone at 6192 ft. Age: ?Tertiary. Hystrichosphaerids sparse. Pollen content low.

Moyne River (see p. 110). *Hystrichosphaera furcata* present, pollen content moderate.

Western Australia:

Perth Bore. Bore put down in Government House grounds, Perth, at 81-82 ft. Grey marine clay. Age: ?Tertiary. Hystrichosphaerids sparingly present. Pollen grains sparse.

Description of Types

1. *Hystrichosphaera furcata* (Ehrenberg) O. Wetzel.
(Plate I, Figs. 13-17)

Origin of type: Cretaceous flints of Delitzsch in Saxony. Other records include Cretaceous flints of the Paris basin (Deflandre 1937), Eocene of Belgium (Pastiels 1948) and the Miocene rock salt deposit near Cracow (Kirchheimer 1950).

The Australian examples of *Hystrichosphaera furcata* are spherical shells 26-55μ in diameter which are ornamented with a number of radiating bi- or tri-furcate appendages 7-18μ long. The overall diameter of the specimens ranges from 39-96μ.

The membrane of the shell is smooth or finely granular (plate I, fig. 15), a variation that is in conformity with the European representatives of this species (Deflandre 1937, p. 15). It is marked out into rectangular or hexagonal fields by usually clearly defined sutures at the junction of which the appendages are situated (plate I, figs. 13, 15).

Occurrence: Sediments at Anglesea, Gellibrand River, Balcombe Bay, Moyne River, and Perth, the ages of which range from Oligocene to Quaternary.

2. *Hystrichosphaeridium tubiferum* (Ehrenb.) Deflandre ..
(Plate 2, fig. 24)

Origin of type: Cretaceous flint, Delitzsch, Saxony. Other occurrences include Cretaceous of Paris Basin (Deflandre), Cretaceous of England, and Eocene of Belgium (Pastiels).

The general appearance of the much-flattened shell shown in fig. 24 bears sufficient resemblance to *Hystrichospaeridium tubi-*

ferum for its inclusion in this species. It measures 68 x 42μ, is oval in outline, and shows the insertion of seven (possibly eight) radially disposed, tubular appendages about 34μ long. These have cup-shaped ends with fringed edges. The shell-membrane is granular.

Occurrence: Nelson Bore at depth of 6192 ft.

Comments: According to Deflandre (1937) *Hystrichosphaeridium tubiferum* is a variable species. Apparently the shell may be either spherical or ellipsoidal and the appendages may vary considerably in number and length. The small number, at most eight, in the Australian example is exceptional but not sufficiently far from Wetzel's minimum (Deflandre 1937, p. 21) of ten to remove it from *H. tubiferum.*

3. *Hystrichosphaeridium truncigerum* Deflandre
(Plate II, figs. 21-23)

Origin of type: Cretaceous flints and shingles of the Paris Basin.

Several specimens have been observed which very closely resemble *Hystrichosphaeridium truncigerum.* These are more or less spherical shells about 50-70μ in diameter (not counting appendages) with radially arranged appendages of varying widths. Usually the larger appendages are of even width and their ends are truncate, but sometimes, as in the example shown in plate II, figs. 21, 22, they widen distally and are more vase-like. Their width varies from 3-23μ and their length from 10-27μ. The walls of the appendages are traversed by slender fibrils which run from apex to base at which point they radiate out into the shell. The main fibrils are connected together by delicate transverse and oblique strieae. The membrane of the shell appears to be granular.

Occurrence: Sediments near Gellibrand River and Anglesea.

Comments: The reference of such forms to *Hystrichosphaeridium truncigerum* seems justified, although their shells are larger than those of the French examples and the small appendages appear to be less numerous. They agree, however, with these, in the occurrence of tubular appendages of different widths and truncate form, and the presence in their walls of delicate fibrils.

4. *Hystrichosphaeridium geometricum* Pastiels
(Plate II, fig. 25)

Origin of type: Eocene argillites, Ypres, Belgium.

A number of examples of *Hystrichosphaeridium geometricum* have been isolated from the deposit near the mouth of the Gelli-

brand River. All show the polygonal form, the short, simple or forked, spiny appendages and the smooth surface, typical of this species. The diameter of the shell (not counting appendages) ranges from 44-60μ and the length of the appendages from 5-15μ. Both measurements approximately closely to those of the Belgian examples.

The identity of this type is clearly evident when fig. 25 of this paper is compared with fig. 8 on plate 4 of Pastiel's publication (1948).

Hystrichosphaeridium spp.
(Plate II, figs. 26-30)

The two specimens shown in figures 26, 28 are possible representatives of the group of the Hystrichosphaerids typified by *Hystrichosphaeridium hirsutum* (Ehr.), *H. spinosum* White, and *H. pseudohystrichodinium* Defl. (see (Lejeune-Carpentier 1941). Both seem nearer to *H. pseudohystrichodinium* than to either of the other two species but differ from all three in having a large opening or "pylome" at one end of the shell. For this reason, their reference to the Radiolaria may have to be considered. *H.* sp. *a.* shown in optical section and surface view in figs. 26, 27 was isolated from the type Balcombian deposit at Balcombe Bay. It is a large ellipsoidal shell 75 x 83μ (not counting appendages) with numerous stiff, slender, radiating appendages. These are 13-18μ long and are inserted by means of fine "stilts" either separately or in pairs on the surface of the shell. Towards one end of the shell there is an angular opening or "pylome".

H. sp. *b.* The shell shown in fig. 28 was isolated from the Anglesea sandstone. It is smaller (44 x 55μ) than that of *H.* sp. *a,* is roughly ovoid, and slightly concave at the narrower end. The appendages are numerous, slender and stiff, about 10-23μ long, shorter and incurved at the concave end. The surface of the shell is rather coarsely granular. There is a relatively large opening near the wider end of the shell.

H. sp. *c.* This is a still smaller form with the same type of appendage. The shell (figs. 29, 30) has a diameter of about 31μ and the rather stiff appendages about 13μ long have slightly flattened tips and are inserted on the shell by means of short, slender "stilt-like" filaments. At about the middle of the convex surface there is a relatively broad funnel-like outgrowth. The surface of the shell is very finely granular.

This type was isolated from the sandstone near the mouth of the Gellibrand River.

Hystrichosphaeridium cf. *hirsutum* (Ehr.) Defl. (1937)
(Plate 1, fig. 20)

The shells included under this heading are more or less spherical, about 26-44μ in diameter (not counting appendages) with numerous, radially arranged, filiform, flexuous appendages from 5-15μ long. The overall diameters range from 41-60μ. The surface of the shell is granular.

Occurrence: Tertiary clay at Werona, Victoria.

Comments: This microfossil is rather common at this locality. It is not unlike the figure of *Hystrichosphaeridium* cf. *hirsutum* given by Deflandre (1947, fig. 15). However, since the deposit in which it occurs is of freshwater origin, I prefer to leave such questions as its identity and occurrence in the deposit, that is whether it is a primary or secondary constituent, completely open for the present.

Micrhystridium cf. *reticulatum* Deflandre
(Plate II, figs. 31, 32)

Origin of type: Cretaceous flint and shingle of the Paris basin.

The genus *Micrhystridium* as defined by Deflandre includes small globular Hystrichosphaerids with diameters of less than 20μ.

The specimen illustrated in figs. 31, 32 comes under this category and agrees closely with Deflandre's species *M. reticulatum*.

It is a spherical shell 18μ in diameter with radiating appendages of about 5μ, the overall diameter being 27μ. It bears a wide-meshed reticulum at the angles of which the appendages are situated. The appendages are straight and narrow gradually towards minute truncate apices. The surface of the shell is granular.

Occurrence: Sediments near the mouth of Gellibrand River.

Comment: This example bears a great resemblance to the single specimen upon which *M. reticulatum* was based. The only feature in which the two specimens disagree is the texture of the shell-membrane, which is smooth in the French example, granular in the Australian.

Micrhystridium cf. *ambiguum* Deflandre
(Plate II, fig. 33)

Origin of type: Cretaceous flints of Paris Basin.

The shell is spherical 20μ in diameter with numerous closely placed radiating appendages about 7μ long. The overall diameter is 30μ. Most of the appendages are terminally forked and the branches recurved. The surface of the shell is slightly granular.

Occurrence: Oligocene sandstone near Anglesea.

Comments: Only one shell of this type has been seen. It does not agree exactly with *H. ambiguum* in which the appendages are shorter relative to the diameter of the shell than in the Anglesea specimen. It is distinct from *M. reticulatum* Deflandre in the absence of a surface reticulum.

Micrhystridium sp.
(Plate II, fig. 34)

The shell is more or less spherical 13-19μ in diameter (not counting appendages), with fine, rather stiff, radially arranged appendages, 3-5μ long. The apices of the appendages are slightly flattened and occasionally forked. The surface of the shell is smooth.

Occurrence: Gellibrand River, Victoria.

Cannosphaeropsis cf. *caulleryi* Deflandre
(Plate II, figs. 35-40)

Shells that are comparable with *Cannosphaeropsis caulleryi* as figured by Deflandre are relatively numerous in the bed near the Gellibrand River. Usually they are rather crumpled, folded or fragmentary.

The shell itself is somewhat ovoid, 43-74μ in diameter and invested by an outer delicate net-like envelope of unequal mesh formed by the branching and anastomosis of the fine radially arranged stems which link it to the central shell. Minute spines (Plate II, fig. 40) are sometimes present on the outer edges of the "net". The overall diameter ranges from 67-115μ. The surface of the shell is finely granular.

Occurrence: Oligocene sandstone near the mouth of the Gellibrand River and Anglesea.

Comments: This type has been referred to *Cannasphaeropsis* rather than to *Membranilarnax* O. Wetzel which to some extent it resembles, on account of the radial arrangement of the branched stems which support the covering network. In some species, at least, of *Membranilarnax* the axial "stems" are restricted to an equatorial zone.

Of the six species of *Cannasphaeropsis* that have been described the descriptions of only two—*C. utinensis* O. Wetzel and *C. reticulensis* Pastiels have been available. However, figures of all have been considered, and it is on the basis of the resemblance between the Australian shell and the one of *C. caulleryi* figured by De-

flandre (1947, fig. 54) that the present tentative reference to this species has been made.

It should perhaps be mentioned that the example illustrated in plate II, fig. 36, of this paper has a coarser net than most of the other specimens and possibly approaches more closely to *C. reticulensis* Pastiels than they do.

Cannosphaeropsis urnaformis n. sp.

(Plate II, fig. 41-43)

The type specimen of *Cannosphaeropsis urnaformis,* shown in surface view and optical section in plate II, figs. 41, 42, is a smooth ovoid shell 44 x 55μ with approximately twelve short, broad, radially arranged vase-shaped appendages. The latter measure about 20μ across the base and about 30μ across the rim and are 15-18μ long. The walls of the appendages are much perforated, the holes frequently extending from the rim to the prominent annular thickening present at the point of junction of an appendage with the shell-membrane. The rim is entire and slightly fluted. The appendages of this specimen are free from one another. A second example, however, suggests that they may not have always been so, since two of its appendages (plate II, fig. 43) are definitely attached to one another by a short and delicate strand.

The surface of the shell is finely granular.

Occurrence: Oligocene sandstone, Anglesea, Victoria.

Comments: This type has been classified with *Cannosphaeropsis* rather than with the species of *Hystrichosphaeridium* with tubular appendages, on account of the perforated character of the appendages and the probability that these were connected together by delicate strands or tubes. The general resemblance of *C. urnaformis* to one of the figured specimens of *H. salpingophorum* Deflandre (Pastiels 1948, plate III, fig. 7) has been noticed but the walls of the vase-shaped appendages of this and other examples of *H. salpingophorum* are entire.

Some of the large appendages of *Cannosphaeropsis aemula,* judging from Deflandre's drawing* (1947, fig. 5), are also vase-shaped and perforated distally, and thus rather like those of *C. urnaformis.* They are connected to one another and to other more slender, forked branches which occur by long, loose, wavy, narrow connecting tubes. The appendages of *C. urnaformis,* on the contrary, are all alike, they are completely perforated and if they were connected it seems probable that the strands between them were short and extremely delicate.

*A description of this species has not been seen.

Palæoecology

Of the three microfossil types considered in this paper *Botryococcus braunii* is of least importance in any palæoecological study since it can live in either salt or fresh water. On the other hand *Pediastrum* being a freshwater alga and the Hystrichosphaerideae being components of the marine plankton are more valuable indices in this respect. Thus the occurrence of *Pediastrum* with *Botryococcus* in the Cootabarlow shale and Werona clay confirms that both are freshwater lake deposits. In contrast the association of Hystrichophaerids with *Botryococcus* in the Anglesea sandstone and Moyne River clay indicates that these deposits accumulated in or near salt water, but since *Botryococcus* is present, at no great distance from a marine shore-line.

The pollen content in both cases throws some light on the type of vegetation growing in the vicinity of these particular accumulating sediments. One of the most frequently recurring pollen-grains in the Moyne River deposit is one referable to the Chenopodiaceae. Its presence is suggestive of the probable existence of nearby coastal or salt-marsh formations, that is, conditions possibly somewhat similar to those prevailing, at present, along the south-eastern coast of South Australia. Erdtman (1943, p. 82) writes as follows, "Plants belonging to this family are often characteristic of salt marshes and the occurrence of *Chenopodiaceae* pollen in marsh peat and certain sediments may be an indication of changes in the shore-line, etc."

The pollen content of the Anglesea sandstone is high and varied, and includes a number of tree pollen grains. It would seem therefore that a forest was not far removed from the accumulating sediments.

The lithological agreement existing between the sandstone beds near the mouth of the Gellibrand River and at Anglesea has already been mentioned (p. 112). The microfossil content of the two deposits is also closely similar but not exactly so. *Botryococcus* has not been observed in the Gellibrand River sandstone, whereas it has been consistently present, although in rather small numbers, at Anglesea. Several types of *Hystrichosphaerids,* for example *Hystrichosphaera furcata, Hystrichosphaeridium truncigerum* and *Cannosphaeropsis* cf. *caulleryi* are common to both, but the number of individuals seems higher at Gellibrand River than at Anglesea. The pollen content of the former deposit is correspondingly lower than that of the latter. Whether these facts suggest that the conditions of sedimentation were slightly different

in the two areas can only be decided after a more comprehensive examination of the two deposits has been made.

When using microfossils such as the Hystrichosphaerideae for palæoecological purposes it must be remembered that these and other types may be transferred from older to younger deposits. Iversen (1936) has reported the secondary occurrence of *Pediastrum,* "Hystrix", and Tertiary pollen grains in boulder clay from North Jutland, and Kirchheimer (1950) has suggested the possibility that microfossils from the Miocene Salt deposit at Wieliczka were washed into the developing deposit from the underlying Cretaceous beds.

In this connection, reference to the occurrence of the microfossil described here as *?Hystrichosphaeridium* cf. *hisutum* (Ehr.) Defl. from the Tertiary clay at Werona seems relevant. If this type were to be accepted as a member of the Hystrichosphaerideae its presence in this fresh-water deposit could only be explaind on the assumption that it was a secondary derivative from some older deposit.

Distribution of the Hystrichosphaerideae

Much has still to be learnt concerning the vertical range of the individual types of the Hystrichosphaerideae. The present investigation has been neither sufficiently comprehensive nor precise to add much to the knowledge already available. However, it has shown that the group as a whole was well represented in southern waters during the Tertiary period and, if the identifications are correct (about some of them there is little doubt), has demonstrated the cosmopolitan nature of such species as the following:

Hystrichosphaera furcata is known from European Cretaceous, Eocene and Miocene deposits. Its range in the Australian beds so far examined is from Oligocene to Quaternary.

Hystrichosphaeridium tubiferum which is common in the Cretaceous of Britain and Europe, and also occurs in several European Eocene deposits, has been isolated from a Victorian sediment of uncertain age.

Hystrichosphaeridium truncigerum. Known from Cretaceous flints of the Paris Basin, occurs in Victorian strata regarded as belonging to the Oligocene period.

Hystrichosphaeridium geometricum recorded only from Eocene beds in Belgium, also occurs in one of the Victorian deposits believed to be of Oligocene age.

Cannosphaeropsis caulleryi with which one of the Victorian Oligocene types has been compared, was originally described from French Jurassic marls.

The Hystrichosphaerid population of the Australian Tertiary rocks is actually greater than is indicated by this account. Several varieties more difficult to place systematically have been purposely omitted.

Acknowledgments

I wish to acknowledge my indebtedness to the following for providing the samples from which the microfossils recorded in this paper were isolated: Dr. J. H. Dulhunty, University of Sydney; Dr. D. E. Thomas, Mines Department, Melbourne, Mr. W. Baragwanath, Mines Department, Melbourne; Dr. A. B. Edwards, C.S.I.R.O., Melbourne, Mr. G. Baker, C.S.I.R.O., Melbourne; Mr. E. D. Gill, National Museum, Melbourne; Mr. A. Coulson, Education Department, Melbourne; and Mr. S. Dickinson, Department of Mines, Adelaide.

Thanks are due also to Dr. A. B. Walkom, Australian Museum, Sydney; Dr. Britta Lundblad, Riksmuseet, Stockholm; Mr. E. D. Gill, and Miss D. Garrett, State Electricity Commission, Melbourne, for prompt assistance with literature.

This work was made possible by considerable financial assistance from the Commonwealth Scientific and Industrial Research Organization.

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EXPLANATION OF PLATES

The photographs are the work of I. Cookson. All the figures are from untouched negatives.

Plate 1

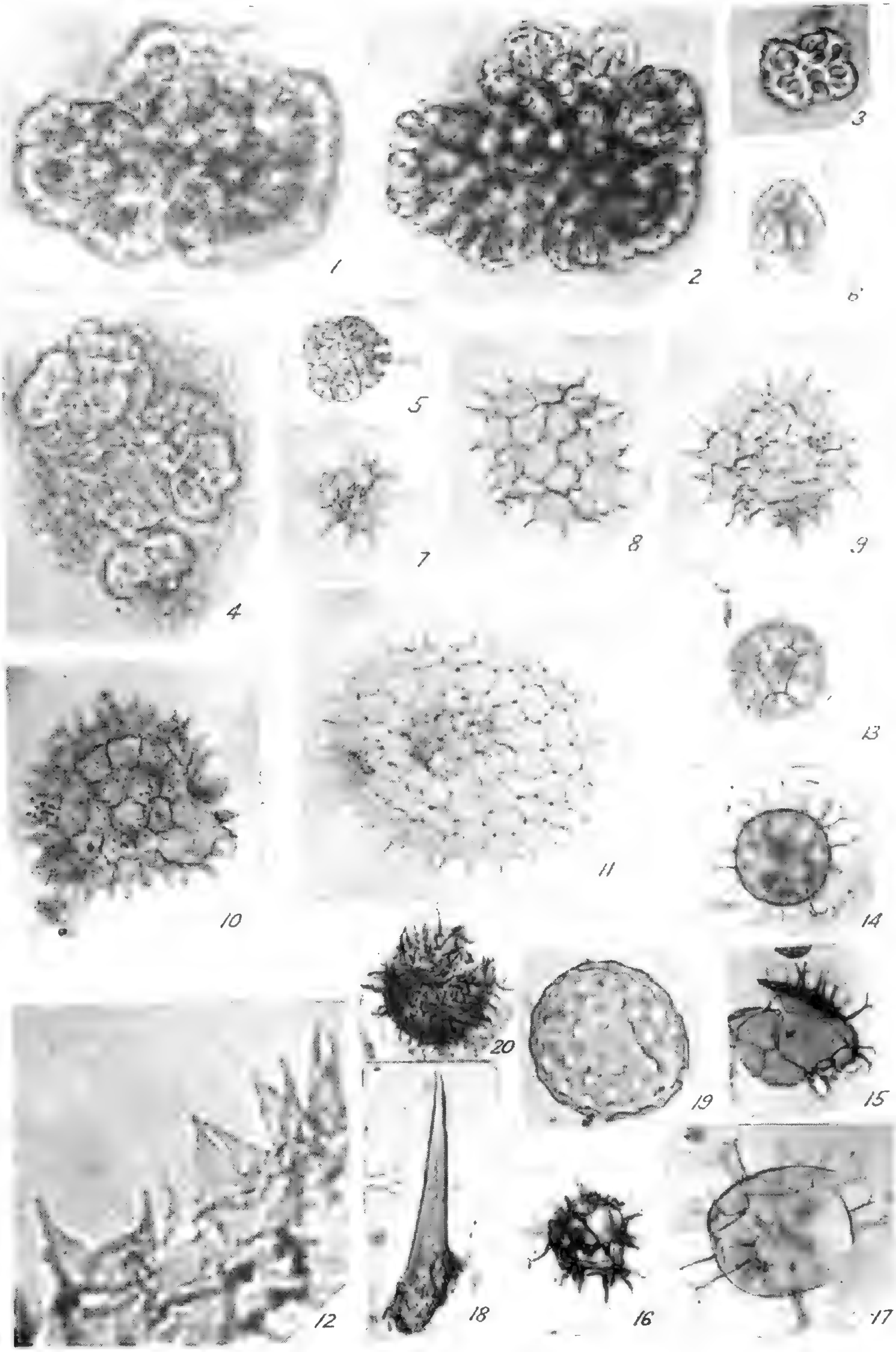
Figs. 1, 2. *Botryococcus braunii*—A large colony in surface view and optical section. Werona, Victoria. x 800. P 15650*.
Fig. 3. *B. braunii*—A small colony showing connecting strands between daughter colonies. Lal Lal, bore 60 at 187 ft., Victoria. x 800. P 15655.
Fig. 4. *B. braunii*—A large group of loosely connected daughter colonies. Warlands Creek, New South Wales. x 600. P 15633.
Fig. 5. *B. braunii*—Anglesea, Victoria. x 400. P 15634.
Fig. 6. *B. braunii*—Side view of a four-celled group showing two of the cups. Warlands Creek. x 800.
Fig. 7. *Pediastrum boryanum*—An eight-celled colony. Cootabarlow Bore, South Australia. x 400. P 15646.
Figs. 8, 9. *P. boryanum*—Two sixteen-celled colonies. Cootabarlow. x 400. Fig. 8, P 15647.
Fig. 10. *P. boryanum*—A thirty-two-celled colony. Cootabarlow. x 400. P 15648.
Fig. 11. *P. boryanum*—An approximately sixty-four-celled colony. Cootabarlow. x 400. P 15649.
Fig. 12. *P. boryanum*—Marginal cells. Cootabarlow. x 800. P 15647.
Figs. 13, 14. *Hystrichosphaera furcata*—Surface view and optical section of a shell. Balcombe Bay, Victoria. x 400. P 15654.
Fig. 15. Portion of a shell of *H. furcata*. Gellibrand River, Victoria. x 400. P 15639.
Fig. 16. *H. furcata*. Anglesea, Victoria. x 400.
Fig. 17. *H. furcata*. Moyne River, Victoria. x 400. P 15652.
Fig. 18. A thick-walled hair from peat at South Ecklin, Victoria. x 400. P 15644.
Fig. 19. A cribellate pollen grain of chenopodiaceous type. Moyne River. x 600. P 15653.
Fig. 20. ?*Hystrichosphaeridium* cf. *hirsutum* (Ehr.) Defl. Werona, Victoria. x 400. P 15651.

Plate II

Figs. 21, 22. *Hystrichosphaeridium truncigerum* in surface view and optical section. Gellibrand River. x 400. P 15639.
Fig. 23. Another shell of *H. truncigerum* showing a small appendage at *S.* Gellibrand River. x 400. P 15640.
Fig. 24. *Hystrichosphaeridium tubiferum.* Nelson Bore at 6192 ft., Victoria. x 400. P 15645.

*References so given are the registered numbers in the palaeontological collection of the National Museum.

Fig. 25. *Hystrichosphaeridium geometricum*. Gellibrand River. x 400. P 15640.
Figs. 26, 27. *Hystrichosphaeridium* sp. *a*.—Surface view and optical section. Balcombe Bay. x 400. P 15654.
Fig. 28. *H.* sp. *b*. Anglesea. x 400.
Figs. 29, 30. *H.* sp. *c*. Gellibrand River. x 400. P 15641.
Figs. 31, 32. *Micrhystridium* cf. *reticulatum*—Surface view and optical section of the same specimen. Gellibrand River. x 400.
Fig. 33. *M.* cf. *ambiguum*. Anglesea. x 400. P 15635.
Fig. 34. *Micrhystridium* sp. Gellibrand River. x 400. P 15642.
Fig. 35. *Cannosphaeropsis* cf. *caulleryi*. Gellibrand River. x 400. P 15643.
Fig. 36. *C.* cf. *caulleryi*. Another specimen from the Gellibrand River. x 400. P 15643.
Fig. 37. *C.* cf. *caulleryi*. Anglesea. x 400. P 15636.
Figs. 38, 39. *C.* cf. *caulleryi*. Gellibrand River. x 400. P 15639.
Fig. 40. *C.* cf. *caulleryi*. Portion of outer network. x 800.
Figs. 41, 42. *Cannosphaeropsis urnaformis* n. sp. Surface view and optical section of the same specimen. x 400. P 15637.
Fig. 43. *C. urnaformis*. Portion of the shell of a second specimen showing the linking of two vase-shaped, perforated appendages by a short connecting strand. Anglesea. x 600. P 15638.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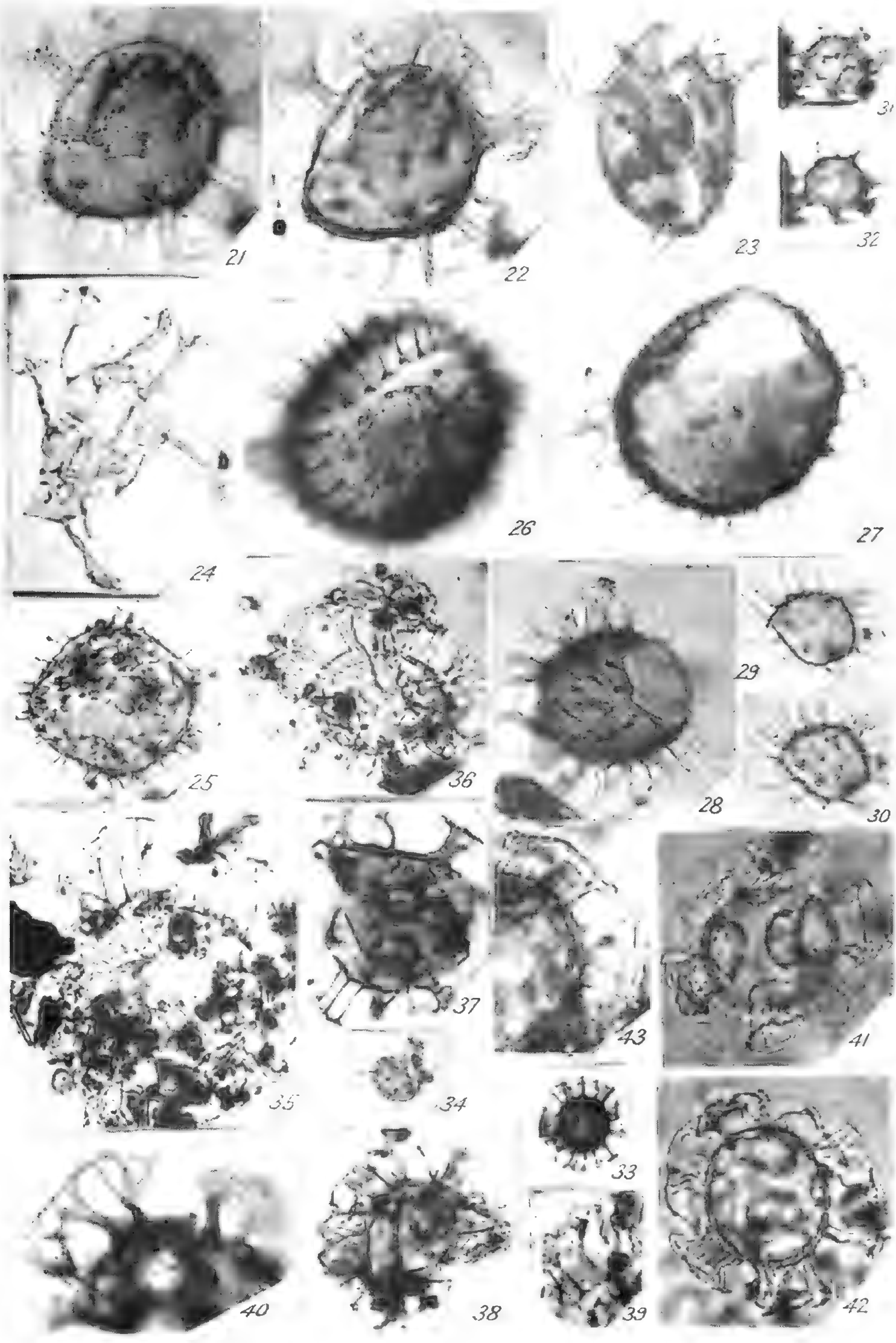
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THE RELATIONSHIP OF *CYCLAMMINA*-BEARING SEDIMENTS TO THE OLDER TERTIARY DEPOSITS SOUTH-EAST OF PRINCETOWN, VICTORIA

By George Baker, M.Sc.

INTRODUCTION

Dr. I. C. Cookson has recently recognized and described (this volume, pp. 107-123) a number of marine and terrestrial micro-organisms from a deposit of carbonaceous sandy shale outcropping in the sea cliffs approximately three-quarters of a mile south-east of Point Ronald, at the mouth of the Gellibrand River, near Princetown, parish of Latrobe, counties of Heytesbury and Polwarth, Victoria. Samples of this deposit were treated by the author in 1942, and the residues from hydrofluoric acid digestion submitted later to Dr. Cookson for investigation.

The carbonaceous sandy shale was re-examined in the field in December, 1951, with a view to seeking further evidence for comparison with the marine, carbonaceous beds at Demon's Bluff near Anglesea and at Point Addis midway between Torquay and Anglesea, Victoria. Dr. Cookson describes a number of similar marine and terrestrial micro-organisms from the carbonaceous sandy deposits comprising the Anglesea cliffs.

As a result of the discovery of other marine fossils during re-examination of this deposit, much more is now known of its nature. The relationship of the carbonaceous sandy shale to other Older Tertiary sediments south-east of the mouth of the Gellibrand River, is herein recapitulated in the light of further advances in our knowledge of Victorian Older Tertiary geology. A revised stratigraphical nomenclature has been employed in an attempt to simplify the naming of parts of the sedimentary succession, and to bring the nomenclature into general conformity with the principles of the current Australian Stratigraphic Code (Raggatt, 1950).

NATURE, FOSSIL CONTENT AND RELATIONSHIPS OF THE DEPOSITS

Where sampled, at Wilkinson's No. 8 specimen locality (see Baker 1943, fig. 1, p. 238), the carbonaceous sandy shale constitutes the lower 25 feet of the cliff face, the base of which is masked by recent beach sands that are here some five feet above normal high tide level. This bed of carbonaceous sandy shale occurs in the

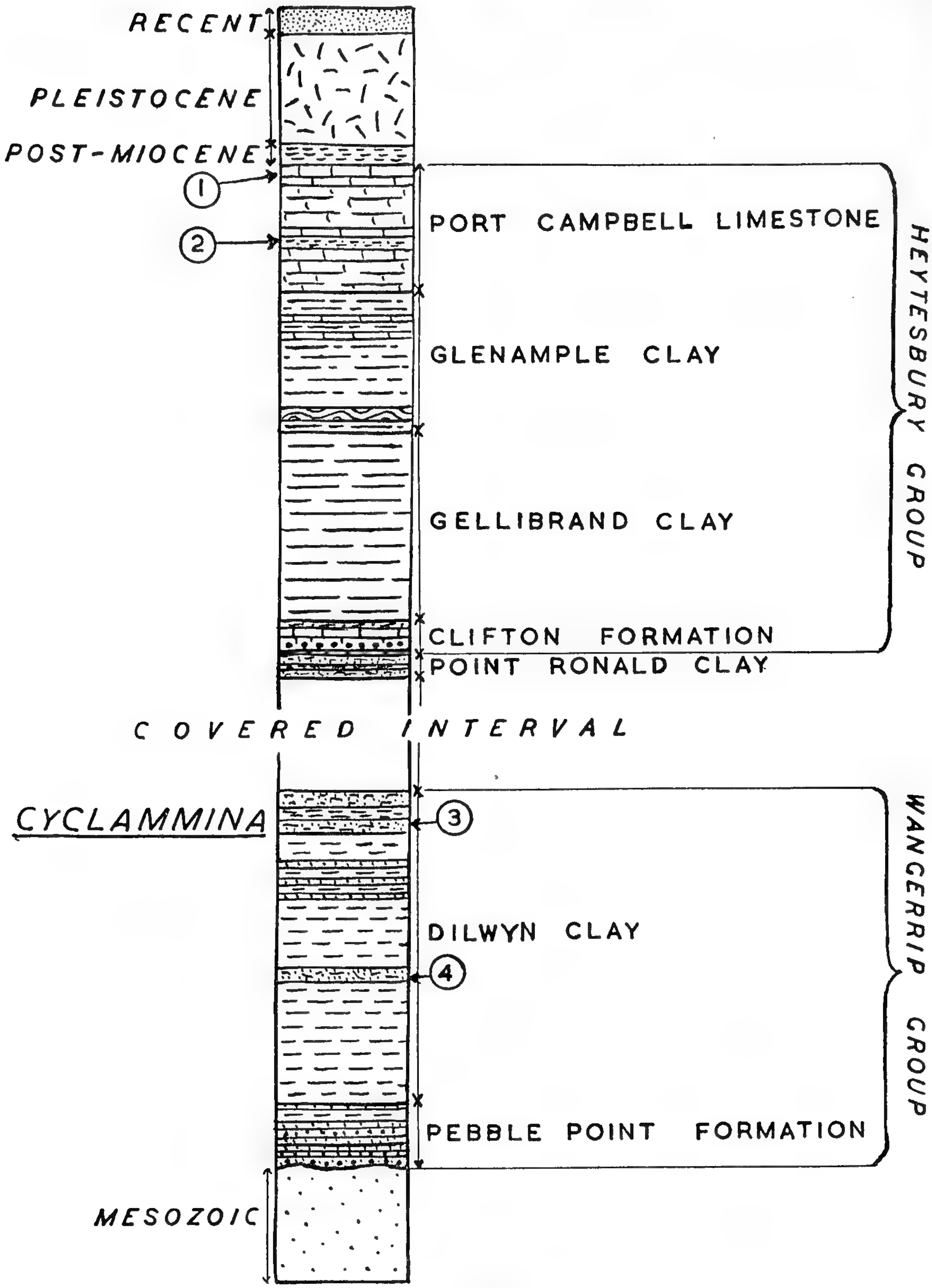

FIGURE 1.

Stratigraphical Column showing conformable relationship of *Cyclammina*-bearing carbonaceous sandy sediments to overlying and underlying sediments. 1 = Peterborough Member; 2 = Rutledge's Creek Member; 3 = Princetown Member (*Cyclammina*-bearing); 4 = Rivernook Member. (Thicknesses of the various formations can be assessed from Baker 1950, figure 2, p. 29.)

uppermost part of a series of conformable Older Tertiary sediments that dip at up to 5° in a direction a little north of west. The deposit comprises portion of the beds previously named the Princetown Beds recently placed in the Latrobe Formation (Baker 1950, p. 30), but now included in the Wangerrip Group and named the Princetown Member of the Dilwyn Clay (see fig. 1). Ferruginous sandy and clay layers above the Princetown Member, have so far yielded no fossils, and are overlain to the north-west by Pleistocene dune limestone that constitutes a covered interval masking the relationships between younger Tertiary sediments north-west of the mouth of the Gellibrand River and Older Tertiary sediments south-east of the Gellibrand River. To the south-east, the Princetown Member is conformably underlain by carbonaceous clays and shales previously termed "algal clays with copiapite" (Baker 1943, fig. 2, p. 243) in accordance with the nomenclature used in the past for branching markings regarded as being "presumably algal" (Singleton 1941, p. 25). Some of these markings, if not all, are now regarded as non-algal. In the upper part of the Dilwyn Clay, the so-called "algal" clays are interbedded with thin, hard sandstone beds, one of which contains, among other fossils, *Cycloseris tenuis* Duncan (see Baker 1943, p. 240), a coral having an Eocene age in southern France and an Upper Cretaceous to Eocene age in other parts of the world (Felix 1927). Further to the south-east, the Dilwyn Clay contains the interbedded Eocene Rivernook Member, and then passes into the conformable littoral deposits comprising the Pebble Point Formation (Baker 1943, pp. 241-242, Baker 1944, p. 87, Singleton 1943 and Teichert 1943).

Until recently, the carbonaceous sandy shale bed (Princetown Member) at Wilkinson's No. 8 specimen locality has been classed as unfossiliferous, and it has been somewhat uncertain whether the deposit was of marine origin. Lithological and mineralogical resemblances to the carbonaceous sandy beds near Anglesea (Baker 1944, p. 87) which contain marine fossils (Edwards and Baker 1951, p. 44), have led to the belief that the carbonaceous sandy shale south-east of the Gellibrand River was probably of similar age and probably also of marine origin.

Recent falls of large slabs of the carbonaceous sandy shale from steep cliff exposures three-quarters of a mile south-east of the mouth of the Gellibrand River, have now revealed the presence of poorly preserved fragments and a few readily recognizable cross sections of *Cyclammina;* also rare moulds of pelecypods that are largely indeterminate. One external mould, however, has the oval to trigonal shape, the size and the concentric growth lines

suggestive of a *Nucula* or *Nuculana,* although it cannot be specifically compared with *Nuculana paucigradata* Singleton (Singleton 1943) described from the Pebble Point Formation. Another pelecypod mould has the shape and size of *Cucullaea* (*Cucultona*) *psephea* Singleton (Singleton 1943) also described from the Pebble Point Formation. Occasional impressions of the corallum and septae of *Trochocyathus* are preserved in occasional pyritic nodules in the deposit; they resemble the better preserved examples of this coral that is so abundant in the stratigraphically lower sandstone bed containing *Trochocyathus, Odontaspis,* etc.

Cyclammina

The specimens of *Cyclammina* are composed of small, loosely attached grains of quartz that tend to crumble away on exposure, hence it is not surprising that the presence of *Cyclammina* in the carbonaceous sandy shale went unrecognized for some time. Many of the foraminiferal remains are represented merely by subcircular aggregates of small, whitish quartz grains and show no distinct fossil structures. A few specimens exposed as cross sections in the freshly fractured rock are multilocular, and reveal thick-walled, arenaceous forms having concave septae (typical of the "nautiloid" varieties of the foraminifera) and a planispiral arrangement of chambers that are filled with matrix similar to the containing carbonaceous sandy shale; no apertures were evident in any of the specimens discovered, because the forms could not be isolated from the matrix without crumbling. Mr. A. C. Collins has kindly verified this determination of *Cyclammina.*

Branching Markings.

Branching markings resembling in colour and shape the so-called "algal" markings in the upper portions of the Dilwyn Clay, are much more sparse in parts of the carbonaceous sandy shale composing the Princetown Member. Inasmuch as they consist of slender, lighter coloured aggregates of mineral matter from which the carbonaceous, etc., content has apparently been abstracted, and are pipe-like markings without any definite plant-like structures, they are now thought to be possibly due, in large measure, to burrowing organisms (cf. Baker 1944, p. 91).

Iron Sulphide Nodules

Occasional nodules of iron sulphide, similar to the nodules in the carbonaceous sandy beds at Point Addis near Anglesea, are up to three inches in length and are likewise composed of pyrite rather than marcasite (Edwards and Baker 1951, pp. 40-45).

The iron sulphide in the Princetown Member has replaced a few macrofossils as in the deposits near Anglesea, and occasional structures revealed in polished surfaces of the pyrite, are suggestive of bryozoal fragments. Similar genera, however, have not yet been observed at each locality, in the iron sulphide nodules. The nodules are not all composed of massive pyrite throughout, and in parts they enclose small areas of unreplaced carbonaceous sandy shale. Elsewhere, the pyrite in the nodules acts as a cementing medium to detrital grains, just as in the thin bands of pyrite from 2,910 feet in the Nelson Bore at Glenelg in Western Victoria, and as in nodules at Point Addis and in the Lower Eocene Pebble Point Formation. The detrital grains consist largely of sub-angular to sub-rounded quartz grains with occasional rutile grains; these are set in a matrix of pyrite where the clay constituents of such parts of the rock have been completely replaced by pyrite. Narrow threads of pyrite have also penetrated along cracks in some of the quartz and rutile grains. Some of the elongated "nodules" in the Pebble Point Formation consist of pyrite infilling cell structures and replacing the wall tissues of fossil wood. Such have not so far been observed in the Princetown Member, although rare fragments of partially coalified wood are present.

Discussion

Although *Cyclammina* generally has little value as an index fossil (cf. Glaessner 1951, p. 278), its presence in Victorian Older Tertiary deposits has been used in the past for correlation with the *Cyclammina*-bearing beds near Anglesea, i.e. with sediments previously regarded as of Oligocene age. Because of its time range (from Cretaceous to Recent), no stratigraphical value can be attached to its occurrence in the Princetown Member, but its presence here provides a further factor pointing to similarity with the carbonaceous sandy beds near Anglesea and establishes the poorly fossiliferous Princetown Member as being of marine origin.

Glaessner and Parr (see Baker 1943, appendix, p. 252) found no examples of *Cyclammina* in the foraminiferal assemblage so far recognized from the lowest sediments (the Pebble Point Formation) exposed in the Lower Eocene to Paleocene rocks of the Princetown district. Although various other parts of the Dilwyn Clay were searched for *Cyclammina,* both by the late W. J. Parr and by the author, no foraminifera were discovered. Even if *Cyclammina* should occur in these clays below the Princetown Member, it would not necessarily indicate an Oligocene age, be-

cause of its time range, and because the evidence of the shelly fauna in the inter-bedded sandstones is more specifically indicative of a Lower Eocene age for the Group as a whole.

Because the pelecypod moulds in the Princetown Member cannot be directly compared with the pelecypod shells in the Pebble Point Formation, although their shape and size are suggestive of similarities, no importance can be attached to them as far as an age determination is concerned, but being impressions of marine organisms, they further attest the marine origin of the Princetown Member. The same applies to the impressions of corals in the contained pyrite nodules.

The fact that the copiapite-bearing Dilwyn Clay contains branching markings like those in the stratigraphically higher Princetown Member, which is also gypsum- and copiapite-bearing, might suggest the possibility of a similar age, especially in view of the absence of really distinctive fossils from both deposits and the poorly fossiliferous character of each. However, no especial importance is attached solely to the similarity of these markings from the aspect of age correlation, because numerous markings of various size and shape, now mostly regarded as due to burrowing organisms, occur in various parts of the Moonlight Head-Princetown-Port Campbell-Peterborough Tertiary sequence, including the Eocene to Paleocene Pebble Point Formation, the Eocene Dilwyn Clay and its contained Princetown Member, and several of the Miocene formations (e.g. the Glenample Clay) situated east and west of Port Campbell (cf. Baker 1944, p. 91). The larger of these branching markings occur in sandy phases of the Pebble Point Formation and have been shown to possibly result from *Callianassa* (Glaessner 1947, p. 6). More slender markings in the younger Tertiary deposits are evidently probably due to marine worms, but rather larger markings in the Miocene sediments are possibly due to mud-haunting spatangoids and mud-haunting crabs that are found fossil in several of the deposits north-west of the mouth of the Gellibrand River (Baker 1944).

Recently, (Baker 1943, 1950) the tendency has been to place the upper portions of the Dilwyn Clay into the Eocene. With the discovery of *Cyclammina* in the Princetown Member, this carbonaceous sandy shale deposit becomes even more closely allied in character to the carbonaceous sandy deposits near Anglesea. It was because of the general similarity between the two deposits—one at Anglesea and the other, the Princetown Member, near Princetown, that the Latrobe Formation was originally separated from the underlying sediments now classed as the Dilwyn Clay,

and the Latrobe Formation thus became regarded tentatively as Oligocene in age (Baker 1950, p. 30). In view of the conclusions reached in this paper, the term "Latrobe Formation" can now be dropped completely from usage in this area, and the Princetown Member included in the top of the Dilwyn Clay, Wangerrip Group.

Lithologically and mineralogically, there is virtually no significant difference between the Princetown Member and the upper parts of the Dilwyn Clay, nor for that matter throughout the Dilwyn Clay itself. Most variations are generally apparent only, and assignable largely to variability in degree of oxidation from place to place. Interbedded in the Dilwyn Clay are (a) the Eocene Rivernook Member, which is situated approximately half-way up from the base of the Wangerrip Group, and (b) the Eocene fossiliferous sandstone bands (one containing *Trochocyathus* and *Odontaspis,* etc., and the other containing "*Turritella*", etc.) which are situated nearer the top of the Wangerrip Group. Thin layers of clay similar to the major component of the Dilwyn Clay are interbedded with the upper sediments comprising the Pebble Point Formation (Baker 1943, p. 237; 1950, p. 20).

Summing up, the following observations have a distinct bearing upon the relationships of the *Cyclammina*-bearing Princetown Member to the Older Tertiary sediments south-east of the mouth of the Gellibrand River:

(i) All the beds in the sequence from the base of the Pebble Point Formation up to and including the ferruginous sandstone and clay above the Princetown Member are conformable with one another, having similar dips in similar directions.

(ii) The Princetown Member and other parts of the Dilwyn Clay are essentially similar lithologically and mineralogically, are both poorly fossiliferous and both contain iron sulphide nodules with occasional fragmental bryozoal structures.

(iii) Mineralogically, the sandy and gritty phases of the Lower Eocene to Paleocene Pebble Point Formation are essentially similar to the sandstone bands with fossils that are interbedded with the upper portions of the Dilwyn Clay. Glauconite in particular is common to all of these sediments.

(iv) Some bands in the Dilwyn Clay contain branching markings due largely to burrowing organisms, and these are similar to markings in the Princetown Member.

(v) The sandstone bed with *Trochocyathus, Odontaspis,* etc., the sandstone bed with "*Turritella*" and the Rivernook Member that are all interbedded with the Dilwyn Clay (see fig. 1), contain

certain gasteropods that are essentially the same as gasteropods in the Lower Eocene to Paleocene Pebble Point Formation. Moreover, others of the mollusca in these fossiliferous horizons are common to more than one of the horizons (*fide* O. P. Singleton).

(vi) The shelly faunas of the Wangerrip Group are entirely distinct from those of the Upper Eocene at Brown's Creek near Johanna River (*fide* O. P. Singleton), and are entirely distinct from all subsequent Tertiary deposits in Victoria.

(vii) As noted by Glaessner (1951, p. 277), "the fauna (i.e. of the more richly fossiliferous members higher in the Wangerrip Group) resembles that of the Pebble Point Formation, but the distinctive species of these beds have not been found".

(viii) *Callianassa* sp. has recently been found in beds stratigraphically higher than the Pebble Point Formation and the Rivernook Member (from which beds they were originally described by Glaessner in 1947), the sandstone bed containing *Trochocyathus, Odontaspis,* etc., also having an occasional propodus of this decapod crustacean.

(ix) The interbedded Rivernook Member has a foraminiferal assemblage regarded by W. J. Parr (see Baker 1944, pp. 86-87) as similar to that of the Pebble Point Formation.

The sum total of this evidence is interpreted to indicate that all of the Older Tertiary deposits south-east of the mouth of the Gellibrand River belong to one Group that is probably virtually much the same age throughout, namely, Lower Eocene to Paleocene, the age assigned recently (Baker 1943 and 1950, Singleton 1943, Teichert 1943) to only the lower beds (Pebble Point Formation) in the Wangerrip Group. Since the Princetown Member in the Wangerrip Group thus comes to be regarded as Lower Eocene in age, and is shown herein to be closely allied in many characteristics to similar beds exposed in the cliffs near Anglesea, it follows that there is a distinct possibility that the carbonaceous sandy sediments of the Anglesea district may be older than Oligocene.

In the Princetown district, the relationship of the Eocene sediments (Wangerrip Group) to the younger (Oligocene to Miocene) Heytesbury Group that extends from just north-west of the mouth of the Gellibrand River to beyond Peterborough, is unfortunately masked beneath a covered interval (Baker 1950), and any erosional break or possible faulting that might exist in this critical portion of the Tertiary sequence is likely to be under the covered interval, indicated in the following stratigraphical column (fig. 1). This column shows the position of the *Cyclammina*-bear-

ing Princetown Member in relation to beds above and below. For convenience of reference, the stratigraphical column presented in an earlier publication (Baker 1950, p. 29) is reproduced herein, with amendments to the nomenclature:

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Acknowledgment.

The author is indebted to O. P. Singleton, Ph.D., for reading the manuscript and discussing the Older Tertiary sequence of the critical areas east and west of the Cape Otway region on the southern coast of Western Victoria.

Appendix

Since this article went to the press, a preliminary note has been published in the Australian Journal of Science (vol. 14, April, 1952, pp. 143-147), on the "Geology of Tertiary Rocks between Torquay and Eastern View, Victoria", wherein reference is made by the authors, H. G. Raggatt and I. Crespin, to the occurrence of *Cyclammina* in the top 30 feet of purplish-grey fine silty sandstone at Dilwyn Bay, eight miles west of Johanna River.

Dilwyn Bay is in the Moonlight Head district (see Baker 1950—reference list above). The sediments in which Raggatt and Crespin record a new discovery of *Cyclammina,* are partially oxidized portions of the Dilwyn Clay of this paper. The discovery

serves to extend the range of occurrence of *Cyclammina* to lower horizons in the Dilwyn Clay than the *Cyclammina*-bearing carbonaceous sandy shale horizon (Princetown Member) described in this paper.

The sites of discovery of these two occurrences of *Cyclammina*-bearing sediments are two and a quarter miles apart. At each locality, these sediments are members of the same series of strata that outcrop continuously in the cliff sections of the district. All the strata have the same low dip values (up to 5°) in the same direction (north of west). On this basis, it can be estimated that the *Cyclammina*-bearing horizons are separated by a stratigraphical thickness of approximately 550 feet, because faulting in the area is on too small a scale to appreciably affect the calculations, and there is no evidence of repetition of strata due to other causes. Although similar deposits occupy much of the area between these two localities, they have not yet been shown to contain *Cyclammina,* although they do contain occasional shells and shell fragments as well as bryozoa (in pyrite nodules), and are thus marine. Interbedded in the Dilwyn Clay, however, are fossiliferous sandstone members containing better preserved molluscs and decapod crustaceans which are also found in the Lower Eocene to Paleocene deposits comprising the Pebble Point Formation in the Moonlight Head-Princetown district.

SOME VICTORIAN FOSSIL DIATOMS

By B. Tindale

At the request of Mr. E. D. Gill, palaeontologist to the National Museum, I have treated and examined samples of the diatomites listed below with a view to discovering their floral content and ecological relationships. A description of each deposit is given, and the diatom content set out in the accompanying table, so that the occurrences of the species can be readily seen. Wherever possible, I have followed in this table the classification of Dr. Henri van Heurck, ignoring such genera as *Pinnularia* and *Neidium,* both of which are listed under *Navicula* for purposes of simplification.

Sample 1. South Yarra Railway Station

Description. Dark grey, soft, and laminated; easily worked, disintegrating quickly under treatment. The sample contained much sand and many sponge spicules. The diatoms most abundant are brackish and marine types, but associated with them are a few purely freshwater forms. The locality does not seem to have been influenced by tides to the same extent as sample 5 from the Yarra Improvement Works.

Slides: P 15565-7.*

Sample 2. Sewerage Tunnel, South Yarra

Description. Dark grey, soft, and laminated; closely related to sample 1, but differing slightly in the diatom content. The sample contained much fine quartz sand, and sponge spicules were fairly numerous.

Slides: P 15394-5.

Sample 3. Junction of South Yarra and Richmond Main Sewers

Description. Dark grey, soft, and laminated. Although closely related to samples 1 and 2, it appears to have been less subject to tidal influence. Contains a good deal of very fine quartz sand, but sponge spicules are not plentiful.

Slide: P 15600.

*The slide numbers are registered numbers in the Palaeontological Collection of the National Museum.

Sample 4. Church Street Bridge

Description. From 13 feet below high-water. Dark grey, fairly dense, compact, and difficult to clean. Contains much fine sand which appears to be cemented to the diatoms. Closely related to the preceding samples, but from the general content I should think that it has been more subject to the influence of the sea. The types most abundant are marine or brackish forms, and a few freshwater forms are present. Contains a few sponge spicules.

Slide: P 15601.

Sample 5. Yarra Improvement Works

Description. From bottom of old river bed, near Botanical Gardens bridge. Moderately soft, disintegrating easily under treatment. This sample is certainly an estuarine deposit, and appears to have been influenced by the tides to a much greater extent than any of the preceding samples. The most abundant diatom is *Melosira borreri.* As this is a littoral form, its presence in great numbers seems to suggest a close proximity of the actual shoreline. Purely freshwater forms are rare, and the quartz sand content of the sample is rather coarser than in the others. Sponge spicules are not plentiful.

Slides: P 15318-20.

Sample 6. Keilor, Victoria

Description. Dark grey, dry, and granulated. In the first sample of this material sent to me, I was unable to detect any diatoms, although several generous portions were treated. In a later sample, which appeared lighter in colour and somewhat finer in texture, abundant diatoms were found, the greater number of which were brackish or marine. The scarcity of freshwater forms in this deposit is notable. The presence of an occasional *Melosira borreri,* and the great abundance of *Chaetoceros* spores seem to suggest that the environment was a shallow inlet of the sea.

Slides: P 15369-70, 15372.

Sample 7. Coburg, Victoria

Description. Greyish-white, compact, and of considerable hardness. This deposit is a purely freshwater one, the diatoms in greatest abundance being two species of *Melosira.* It appears from the spread of the species to be a lacustrine deposit. The sample contained a number of sponge spicules of two species.

Slides: P 15563-4.

Sample 8. Brunswick, Victoria

Description. Grey, hard, and dense; difficult to break down, and the resulting diatoms much fragmented. The material is of freshwater origin, probably lacustrine. In addition to diatoms, it contains numerous sponge spicules.

Slide: P 15396.

Sample 9. Yarraford Avenue, Fairfield

Description. White, soft, laminated in parts, and easily worked. The resulting diatoms are much cleaner than in any of the preceding samples. The majority of the diatoms are of freshwater types, but it contains some that can flourish in brackish water. Purely marine types are absent. Sponge spicules are not numerous.

Slides: P 15561-2.

Sample 10. Craigieburn, Victoria

Description. Pure white, soft, and laminated. Similar in texture and colour to the Talbot and Lillicur diatomites. This is purely a lacustrine deposit, and is related to the Lillicur diatomite, although the flora differs in general composition. The frustules of the larger types are less in evidence. The predominating forms in the Craigieburn sample are two species of *Fragilaria* and two of *Melosira.* Other writers have recorded *Tabellaria* from this deposit, but in all the samples I have examined I was unable to detect any. Sponge spicules are very plentiful.

Slides: P 15598-9.

Sample 11. Grange Burn, near Hamilton

Description. Greyish-white, hard, very dense and compact. Contains much extraneous matter, which is cemented to the individual diatoms. The diatom content is small, and the individual frustrules much fragmented. One peculiar character is, that if the cleaning process is continued, the diatoms appear to fracture; they only appear whole when cemented together in small groups. Few complete frustules of the larger diatoms were seen, so that it is difficult to determine their species, but sufficient fragments were recognized to establish the fact that they are of freshwater origin. Sponge spicules are numerous.

Slides: P 15249-51.

Acknowledgement

I would like to acknowledge the help of my wife in the search for species and their determination.

DISTRIBUTION OF FOSSIL DIATOMS

Locality Numbers	—	1	2	3	4	5	6	7	8	9	10	11
	HABITATS	South Yarra Railway Station	Sewerage Tunnel South Yarra	Junction of Richmond and South Yarra Main Sewers	Church Street Bridge	Yarra Improvement Works	Keilor	Coburg	Brunswick	Fairfield	Craigieburn	Grange Burn
Achnanthes lanceolata	**F**									R		
A. triodis	**F**									C		
Actinocyclus barklyi	**M**	F	C		F	C						
Amphora cymbifera	**M-B**			C								
A. robusta	**M-B**	C	R	R	VR							
Campylodiscus clypeus	**M-B**	F			F							
C. echeneis	**M-B**	R	C	F	F	C	A					
Chœtoceros spores	**M**						A					
Coscinodiscus lacustris	**F**		F		F		A					
C. radiatus	**M-B**				R							
Cocconeis placentula	**B-F**			VR				A		C	F	VR
Cyclotella meneghiniana	**F**	C			F							
C. stelligera	**B-F**			VR						A		
C. striata	**M**	A	C	C	C							
Cymatopleura solea	**F**				VR					F		
Cymbella aspera	**F**									A		
C. cistula	**F**	C	F		C			C			C	
C. delicatula	**F**		F	F								
C. gastroides	**F**	F		F	VR	R	R			F		F
C. ventricosa	**F**									C		
Epithemia gibba	**F**	C		R	R					C	R	
E. gibberula	*****	C	R	F	F		R			C		
E. hyndmannii	**F**						C					
E. turgida	**B-F**				F		C	C				
E. zebra	**F**								R			VR
Eunotia arcus	**F**							F	C			
E. eruca	**F**		R	R	R	R	R	C		C	VR	
E. flexuosa	**F**								R			
E. lunaris	**F**											F
E. major	**F**	C		R	F					C		
E. pectinalis	**F**			R				C		C	R	C
E. prærupta	**F**				R							
Fragilaria harrisonii	**F**							C		A	A	
F. mutabilis	**F**			F				C				
F. virescens	**F**	A								A	A	
Gomphonema intricatum	**F**	F		F		R		C		C	C	R
G. montanum	**F**			F				C				

FREQUENCIES.—A = abundant, C = common, F = few, R = rare, VR = very rare.
HABITATS.— M = marine, M-B = marine and brackish, B = brackish, B-F = brackish and freshwater, F = freshwater, * = all habitats, according to variety.

DISTRIBUTION OF FOSSIL DIATOMS (continued)

Locality Numbers	—	1	2	3	4	5	6	7	8	9	10	11
	HABITATS	South Yarra Railway Station	Sewerage Tunnel South Yarra	Junction of Richmond and South Yarra Main Sewers	Church Street Bridge	Yarra Improvement Works	Keilor	Coburg	Brunswick	Fairfield	Craigieburn	Grange Burn
G. ventricosum	**F**			F						C		
Hantzschia amphioxys	**B-F**						R	C				
Hyalodiscus laevis	**M**	C	C	C	C	C	C					
Mastogloia dansei	**B-F**	A	C	C								
M. grevillei	**B-F**										C	
Melosira borreri	**M-B**		VR			A	R					
M. crenulata	**F**							C	C	C	A	F
M. granulata	**F**										A	F
M. varians	**F**							A		F		
Navicula ambigua	**F**						R	F				
N. aspera	**M**				F							
N. borealis	**F**						VR					
N. cuspidata	**B-F**	F	C							F		
N. elliptica	**B-F**	A	C	C	C							
N. iridis	**F**	F		F				R		F		
N. lauta	**M-B**			R	VR	R						
N. liber	**M**				C							
N. lyra	**M**			R	R	R						
N. macilenta	**F**										C	
N. major	**F**	C	R	A				R	C	C	C	
N. nobilis	**F**								C			
N. smithii	**M**	A	C	F	C		A					
N. subcapita	**F**			C						A	F	
N. viridis	**F**							R				R
N. yarrensis	**M-B**	F	F	C	C	C						
Nitzschia scalaris	**B**	A		A	F	A						
N. spectabilis	**B-F**								C			
N. tryblionella	**B-F**		R	C	F		C	R				
N. vitrea	**B**								C			
Pleurosigma balticum	**M**	R	VR	R	R							
Stauroneis acuta	**F**									F		
S. anceps	**F**	F		F				R	R	F		R
S. phœnecenteron	**F**			F					R	F		R
Surirella ovalis	**B-F**				F							
S. robusta	**F**							F		F		
S. sp. (fragments)		VR										VR
Synedra ulna	**B-F**			C	F			C		C	C	
Vanheurckia rhomboides	**F**	C		F				F				

FREQUENCIES.—A = abundant, C = common, F = few, R = rare, VR = very rare.
HABITATS.— M = marine, M-B = marine and brackish, B = brackish, B-F = brackish and freshwater, F = freshwater, * = all habitats, according to variety.

Mem. nat. Mus. Melbourne, 18, 1953.

PALAEOECOLOGICAL INTERPRETATION OF SOME VICTORIAN FOSSIL DIATOM FLORAS

By Edmund D. Gill, B.A., B.D.
Palaeontologist, National Museum of Victoria

In an accompanying paper, Mr. B. Tindale sets out the determinations he kindly made of diatoms extracted by him from samples of diatomites in the National Museum collection. The following notes are an effort to interpret the results in the light of the writer's studies of the areas concerned.

A. Yarra Delta Floras

The upper part of the Yarra Delta consists of two formations, viz., a lower fossiliferous yellow marine clay into which streams in time gone by cut a terrestrial physiography which reaches far below present sea-level. The clay was thus penetrated by air and oxidized. This buried river system has been infilled and the yellow clay completely covered, by the second higher and younger formation of highly fossiliferous black marine silt, which occurs to about ten feet above low-water Hobson's Bay. One of the commonest shells in this deposit is the stenothermal *Anadara trapezia,* which is almost extinct in Port Phillip Bay but occurs in countless numbers in the delta. The fossil ones are also about twice the size of the extant ones. The species still flourishes further north where the waters are warmer. *Anadara trapezia* is common, too, in the underlying yellow clay. A number of pieces of fossil wood has been found in the black silt, and these have been kindly determined by Mr. H. D. Ingle, B.For.Sc., of the C.S.I.R.O. Forest Products Division, as red gum, *Eucalyptus rostrata.* It is hoped to obtain radiocarbon analyses of both the wood and the shells, thus obtaining an absolute dating for the silt. The yellow clay is regarded as late Pleistocene, and the deep erosion as a function of the last glacial. The black silt is thought to belong to the mid-Holocene Thermal Maximum, because of the presence of such forms as *Anadara trapezia,* and because their elevation above sea-level is consistent with the widely-recognized mid-Holocene ten-foot level. The diatomites in localities 1 to 5 belong to the black silt formation, and so their age is probably mid-Holocene, or a little younger for the deeper layers.

Details of the Yarra Delta localities are given below, and their ecology as shown in the diagrams in text-figure 2 are discussed. This form of representation was designed so that the floras could be viewed as a whole, and their comparisons and contrasts readily seen. Each radial bar represents a species, so the number of bars signifies the richness or poverty in species of the flora. Each

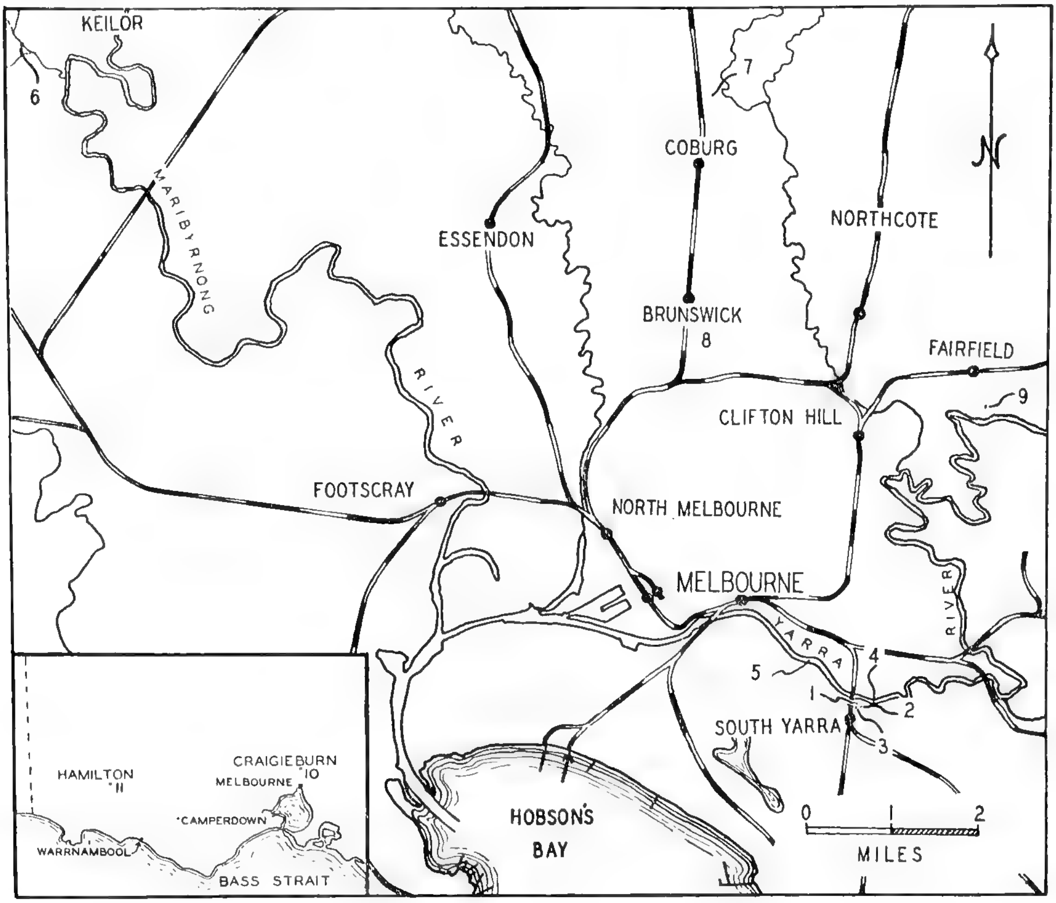


FIG. 1

Localities for fossil diatoms.

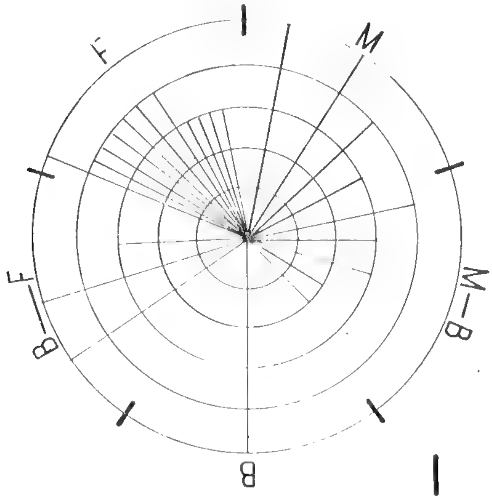
concentric circle represents a degree of abundance (from the centre outwards these are very rare, rare, few, common, abundant), so a glance at the diagram can give an idea of relative frequencies, the lengths of the bars signifying the richness or poverty in numbers of the various species. The division of the circle into sectors covering the various habitats means that the direction of a bar provides information on the ecology of that species. The habitats for the various species are those shown on Mr. Tindale's

list, but *Epithemia gibberula* is omitted because its different varieties occur in marine, brackish, and freshwater environments respectively. Thus much important ecological information concerning a flora can be represented in one diagram. In text-figure 2, the diagrams carry the same locality numbers as appear in Mr. Tindale's paper and this one.

The first claim to find fossil diatoms in Victoria was made by Blandowski (1858), but Mahony (1912) suggests that he confused copi with diatomaceous earth. The first indubitable record is that of Coates (1861), who discovered a deposit at South Yarra, in the Yarra Delta. Card and Dun (1897) comment on this and other Victorian localities, while Dobson (1884, p. 37) recorded diatoms from the silt of the Yarra River and "in a drain dug for the West Melbourne Swamp". Lucas (1887) listed diatoms "proper to brackish or salt water" from "the deposits of the West Melbourne Swamp". Cornwall (1889) refers to living diatoms in the same swamp, while Pritchard (1910) mentions fossil diatoms from there (cf. also Anonymous 1912). Mr. Tindale found sponge spicules but no diatoms in a sample of silt I collected from the Appleton Dock excavations (Slide P 15371 Nat. Mus. Vic.).

Locality 1

The sample of diatomite examined was collected by Mr. F. P. Spry from "Near junction Yarra River and South Yarra Railway Station. Overlaid by silt." Spry, an inspector for the Melbourne and Metropolitan Board of Works, was a keen naturalist who collected much valuable material from early sewerage excavations in Melbourne; he later joined the staff of the National Museum. Mr. M. Teese of the M.M.B.W. has kindly provided me with information which throws light on our localities 1 to 3. A sewerage tunnel was excavated from Richmond, under the Yarra River, and along Yarra Street, which is on the east side of the South Yarra railway station. Spry's material referred to above almost certainly came from this excavation. The floor of the tunnel is 25 feet below low-water, M.M.B.W. datum (i.e. 0·19 feet *below* Admiralty datum, which is used also for military maps and by the Melbourne Harbour Trust, and 0·36 feet *above* the Crown Lands datum). Shepard (1897) reported Spry's specimens as coming from "30 feet below the level of the River Yarra". The Richmond main enters the South Yarra one at a point to be found by producing Domain Road eastwards to Yarra Street. Samples 1 to 3 are all from depth and so differ from the material collected in this vicinity by Coates (1861), which was from the surface.



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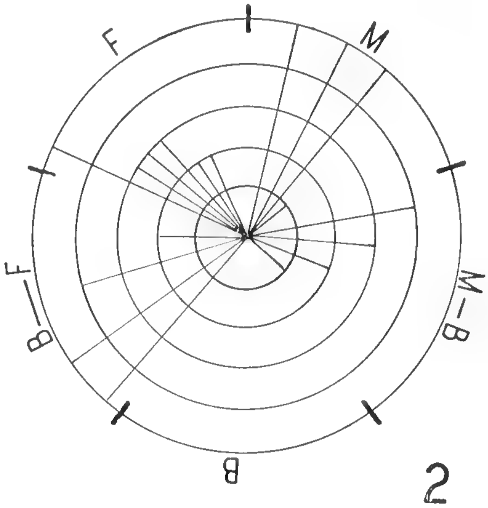

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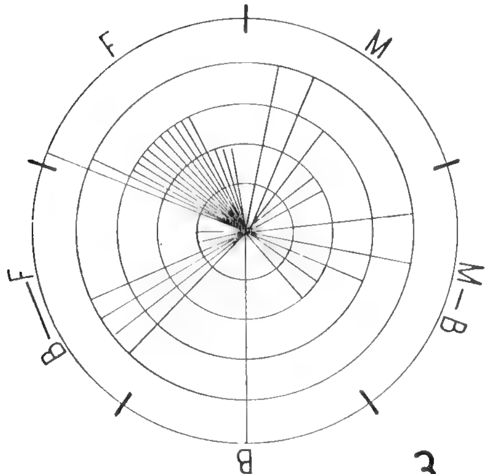

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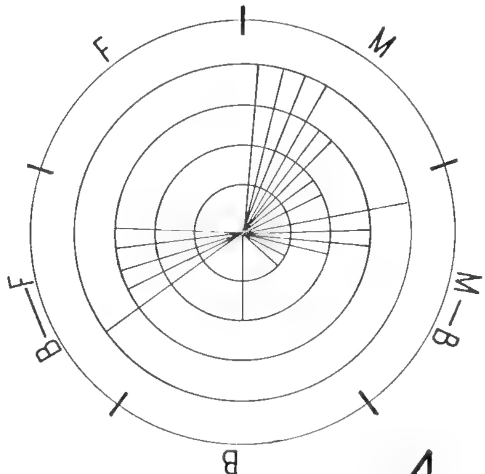

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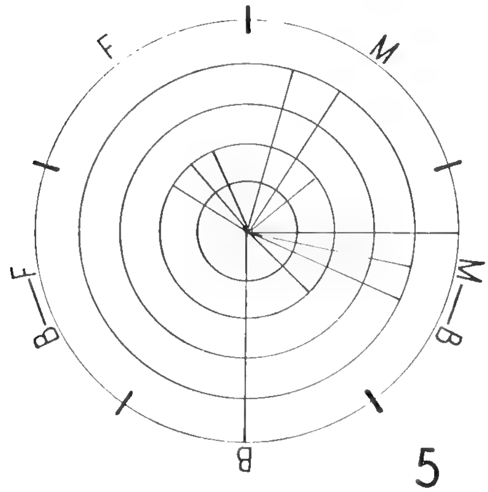

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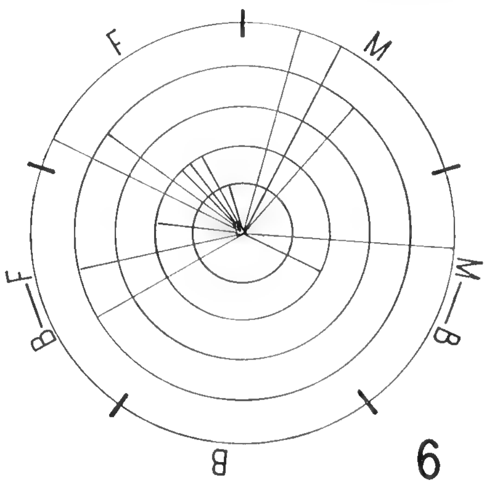

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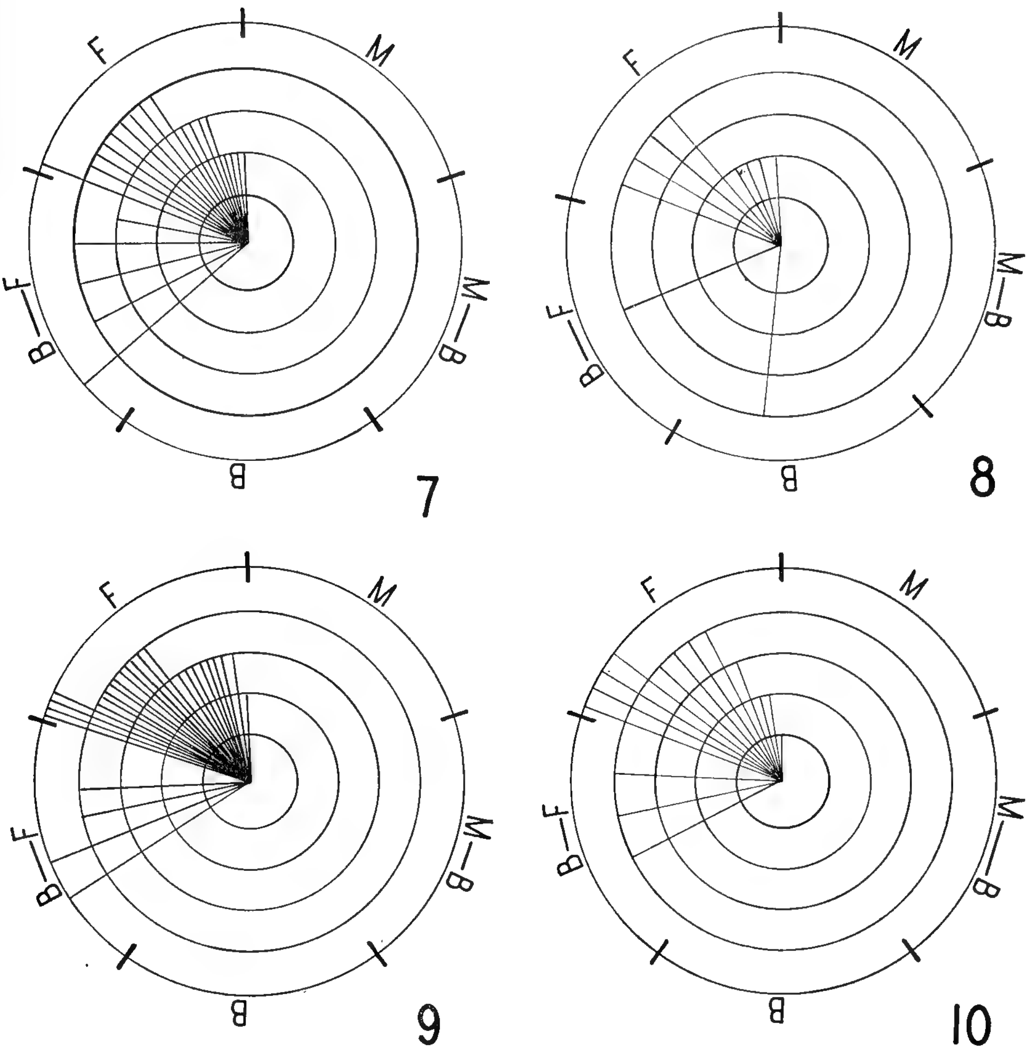

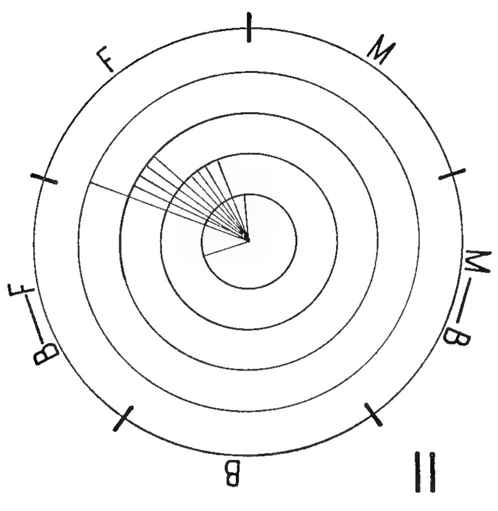

FIG. 2

Diagrams showing number of species, relative number of individuals of each species, and their habitats for the diatom floras discussed in this paper.

Each radius represents a species, and its length the relative frequency of that species, viz. the circles from the innermost to the outermost represent the frequencies very rare, rare, few, common, abundant. The habitats are represented by segments of the circle, viz. M = marine, M-B = marine and brackish, B = brackish, B-F = brackish and freshwater, F = freshwater.

The numbers of the diagrams correspond with the numbers of localities given in the paper.

Coates says the silts here are 60 feet deep, which is to be expected as a result of Pleistocene low level erosion (Gill 1949, p. 39). His identifications are of species from a number of habitats, like the floras of localities 1 to 3, so must be marine because freshwater diatoms can easily be washed into the sea, but not *vice versa.* Thus it may be surmised that the dark silts are marine right to the surface, which finding corresponds with Coates' record of "marine shells, more or less perfect, pieces of cuttle-fish bone, and the débris of echini . . . and numerous foraminiferous shells" (pp. 158-159). He also mentions "spicula of sponge, and the object known as *Dictyocha*" (p. 162).

From text-figure 2 it can be readily seen that the flora of locality 1 is rich in both species and numbers of individuals, and that all five habitats are represented, four by abundant forms, and the fifth by a common form. The sediments are marine, but for most of the species, a thanatocoenose. The presence of so strong an assemblage of freshwater species indicates that a freshwater stream debouched into the estuary at this point; reference to text-figure 1 shows this to be the case. This, and all the other diatomites from the Yarra Delta, are impure.

Locality 2

F. P. Spry collected the specimen of diatomite concerned on 27th April, 1898, from "Sewerage tunnel, near railway station, South Yarra". Lithologically, this is the same as the diatomite from locality 1, but the diatom content is a little different. Text-figure 2 shows the flora to be less in both species and numbers of individuals. The fall in frequency of species is limited almost entirely to the freshwater forms, suggesting that this locality was out of the course of the inflowing creek.

Locality 3

"Junction of South Yarra and Richmond main sewers." From the information given above, it is possible to pinpoint this locality, and to say that the diatomite came from 25 feet or a little less below low-water. If the geological interpretation given earlier in this paper be correct, then the diatomites from localities 1 to 3 were laid down as the sea rose from the glacial low to the mid-Holocene ten-foot level, something like 8,000 years ago.

The flora from locality 3 is remarkable for having 32 species, and that although a marine bed, half this number are restricted freshwater forms. The interpretation of these facts seems to be that this part of the lagoon was right on the line of creek entry.

In the National Museum of Victoria, there are marine fossils in black silt collected on 30th July, 1860, when excavations were in progress for the nearby Cremorne railway bridge. The fossils came from a shaft at a depth of 25 feet. Also in the Museum are marine barnacles obtained by F. P. Spry "31 feet from the surface between Yarra Street and Chapel Street, South Yarra", i.e. between the South Yarra railway station and the Melbourne Boys' High School. These fossils would no doubt be from the sewerage tunnel which passes deep under the school dropping slowly to 25 feet below low-water at Yarra Street. The site is now covered by the playing field of the Melbourne Boys' High School, which 5,000 or 6,000 years ago was occupied by the salt water of a branch of the enlarged Yarra estuary.

Locality 4

"Church Street bridge, Richmond. 13 feet below high-water mark. Presented by A. Lynch, Esq., 20/5/22." So reads the label. The mean tidal range at Williamstown is 2·8 feet, and at Church Street bridge would be about 2 feet. "13 feet below high-water" therefore means about 11 feet below low-water, which figure allows direct comparison with the depth of the specimens from localities 1 to 3.

The flora from locality 4 has diatoms from the full range of habitats, as was the case with those from localities 1 to 3, but the marine element has strengthened relative to the rest. Localities 3 and 4 have 32 and 29 species respectively, with the marine element constituting 17% in the first and 28% in the second. As the site is on the main river course, it would be a tideway and so feel the effect of the marine water more. The non-marine diatoms, and the plant remains also found in the rock, would be washed in by the flow of the river following the receding tide.

It is of interest to note that at whatever depth the samples are taken the lithology is the same—a dark silt with distinctly litoral flora and fauna. The picture this gives is of the deep valleys cut by erosion during the glacial low sea-level being slowly filled, but the waters at no time being either deep or fast-flowing. The molluscs indicate shallow waters, and neither the diatomite nor the fine silts could have accumulated if there had been currents of any appreciable strength.

Locality 5

The dark grey silty diatomite or diatomaceous silt from this locality is labelled, "Yarra Improvement Work. From bottom of old river bed near Botanical Bridge. Collected by F. P. Spry

20/4/49." Kitson (1900, 1902) has given an account of these works, which were undertaken to straighten the course of the River Yarra to aid flood control. In his 1902 paper, he refers to the diatom content of certain beds in this and other parts of the Yarra Delta. In reviews of diatomite deposits, Mahony (1912) and Crespin (1947) have referred to the South Yarra occurrences.

The embayments in the vicinity of the South Yarra railway station and the Botanical Gardens have resulted from the basalt flow forcing the River Yarra against the Silurian rocks of the south bank (see text-figure 1). In the Museum I have found the collections of marine shells listed by Kitson. At that time, Dr. G. B. Pritchard also made a collection from the Friendly Societies' Gardens (now Olympic Park) frontage of the Improvement Works, and this also is in the Museum. The fauna includes a number of small shells of *Anadara trapezia,* the warmer water form so characteristic of the black silt formation. Brander's Ferry was at the downstream end of the Improvement Works, and marine fossils collected from there by F. P. Spry on 5th February 1897 are in the Museum. The writer collected black silt with marine fossils from the excavations for the Swan Street bridge, but the material may not have been *in situ.*

The diatom flora of locality 5 (see text-figure 2) presents an interesting contrast with those of localities 1 to 4. It is definitely marine and has diatoms from a number of habitats, but the freshwater element is reduced to three rare species. This is due to the fact that no stream enters the river at this locality.

Locality 6

Green Gully, Keilor. Mr. A. A. Baker, of the Field Naturalists Club, kindly drew my attention to this occurrence, which Miss Irene Crespin noted in 1926 (p. 103). The deposit is in a miniature island about five feet high in the floor of the small creek which runs down this valley. The site is about three-quarters of a mile in a direct line up the creek from its junction with the Maribyrnong River, south of Keilor. The 100 ft. contour of the military map is practically on the spot. The diatoms occur in a dark carbonaceous sandy clay with plant remains, which in turn is overlain by a light-brownish gravel from which the writer collected a marsupial bone.

The composition of the flora is shown in text-figure 2, and shows the deposit to be a marine one into which a limited amount of freshwater forms were washed. There are no specifically brackish forms. The explanation lies in the youthful physiography of the area. The creek has a deep and steep valley. As the stream

is a small one, no great quantity of freshwater diatoms would grow there, and being steep, no brackish water is likely to accumulate. The occurrence of the brackish-water gasteropod *Coxiella* in a small deposit of limestone a little further downstream may be connected with the retreat of marine waters. However, too little is known at present of the area to provide a fully satisfactory explanation.

B. Freshwater Floras

Omitting Blandowski's doubtful reference, Ulrich's (1875) brief description of the Talbot "infusorial earth" is the earliest account of a Victorian fossil freshwater diatom flora I can find. Krause (1886, 1887), Card and Dun (1897), Herman (1902), Gregory (1903), Kitson (1906), Hunter 1909), Mahony (1912), Chapman (1914, 1919), Dun (1917), Howitt (1936), Thomas (1937), and Crespin (1946) list and/or describe freshwater diatomites in Victoria not mentioned in this paper.

Locality 7

Coburg, Victoria. An account of this deposit is given by Hanks (1930). The locations he describes are in the vicinity of the Batman railway station, and on the west side of Merri Creek. The diatomite is pure, and Mr. Hanks advises me that it is younger than the Newer Basalt. About a mile from this site, Mr. Hanks discovered a clay overlying the basalt and containing *Diprotodon*, a giant kangaroo of the *Macropus titan* group, and other marsupials (Hanks 1931, 1934*a*, 1934*b*). He also found bones of extinct marsupials in deposits under the basalt. On such evidence, and on physiographic grounds, the basalt is considered to be late Pleistocene in age.

The diagram in text-figure 2 presents a sharp contrast with those for the deposits from the Yarra Delta. There is no longer a wide spread of habitats, the radii being limited to two sectors of the diagram. Of 22 species, all are freshwater except for five which are tolerant also of brackish conditions. The diatomite is a typical freshwater deposit, and was probably laid down in a small lake.

Locality 8

Brunswick, Victoria. Mahony (1912) noted the presence of this specimen in the Museum, and Crespin (1947) listed it, but no other information seems to be available concerning the precise origin of the rock or its stratigraphical relationships. Text-figure 2 shows the flora to possess eight freshwater species and two

brackish species. This diatomite varies from most of this series by the presence of definitely brackish water forms.

Locality 9

Yarraford Avenue, Fairfield. Mahony (1912) gives details of this occurrence. Yarraford Avenue runs south from Heidelberg Road to the River Yarra, south-east of Fairfield Park railway station. Stratigraphically, this rather pure diatomite overlies the Newer Basalt, and so is Pleistocene or Holocene in age. The diagram in text-figure 2 indicates a rich flora of 26 species all of which are freshwater except three that are tolerant also of brackish-water conditions.

Locality 10

Craigieburn, Victoria. This locality is 25 miles N.N.W. of Melbourne, and is also known as Mickleham. Its pure diatomite has been worked commercially (Mahony 1912) and is a typical freshwater deposit (see text-figure 2).

Locality 11

Grange Burn, Western Victoria. This is a new locality from which a sample was collected by the writer when investigating other fossil plants at the site. Mr. G. Coates of the nearby town of Hamilton found the outcrop, and with Mr. P. McNaughton kindly guided me to the place. Grange Burn is a creek which runs west from Hamilton, flowing ultimately into the Wannon River. About one and a half miles west of Hamilton, the road to "Clifton" and "The Caves" branches off from the Digby Road, and on the north side of Grange Burn north-west of this corner (immediately east of the east boundary of Mr. P. McNaughton's property) is locality 11 (military map, Hamilton sheet, grid reference 496,346). Text-figure 3 shows a field notebook sketch of the relationships of the rocks. The shaft noted was put down by Mr. Coates on an area stripped of basalt for road metal. The final part of the excavation was made by auger, and finished on hard bedrock believed to be quartz porphyry. The section proved was as follows:

1 ft. 6 in.	yellowish diatomite
1 ft. 6 in.	grey clay
8 ft. 0 in.	black sapropelic clay with pollen and some leaves
	? quartz porphyry
11 ft. 0 in.	Total depth

The talus in text-figure 3 marks the location of a minor fault, a number of which was noted in the area. The creek section shows the diatomite to occur immediately under the basalt. The black clay contains *Araucariacites australis* (see Cookson and Duigan 1951). A nearby bore in the property of Mr. P. D. McNaughton penetrated about thirty feet of basalt, under which was limestone

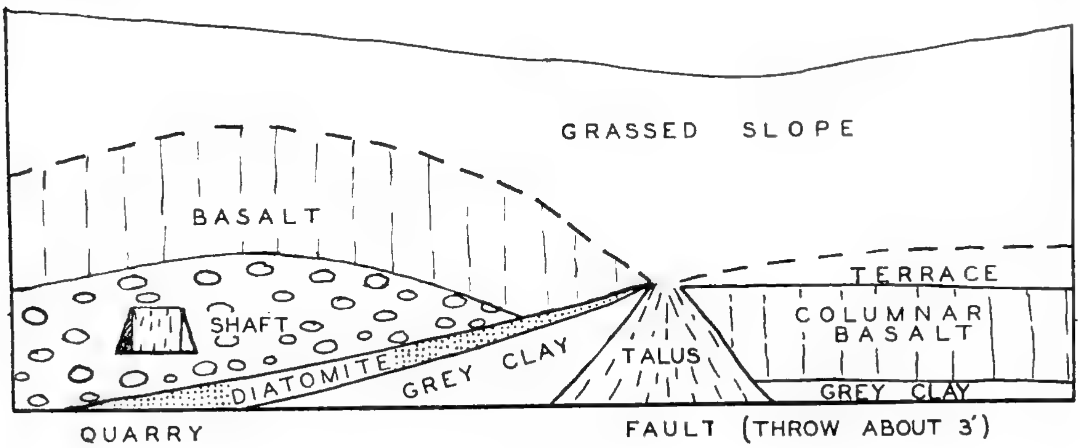

FIG. 3

Diagrammatic sketch showing field relationships of the Grange Burn diatomite. The black clay containing *Araucariacites* pollen came from the shaft shown above.

and shells. Further downstream where the creek has cut through the basalt, the limestone can be seen under the lava. Fossils show the limestone to be marine and of Lower Pliocene age. On it has been developed a podsol soil, and small softwood trees have been preserved by the basalt in place of growth in the soil, though charred by the heat of the basalt. Thus, after the retreat of the Lower Pliocene sea, a terrestrial facies was developed as evidenced by the podsol fossil soil, a marsupial tooth found therein, the trees, leaves, pollen, and diatomite, all of which were covered by the basalt. The pollen and the wood prove the existence of the old Tertiary softwood forest which grew in sub-tropical conditions, and which disappeared with the onset of the comparatively frigid conditions of the Ice Age. The foregoing evidence shows the age therefore to be Upper Pliocene. It is intended to provide later a full account of the late Tertiary ecology as shown by these sections, and its implications for Quaternary studies.

Text-figure 2 shows that the Grange Burn diatomite possesses a typical freshwater flora.

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A NOTE ON THE OSTRACODA *LIMNICYTHERE MOWBRAYENSIS* CHAPMAN 1914, and *L. SICULA* CHAPMAN 1919

By N. de B. Hornibrook
New Zealand Geological Survey

Plate I, figs. 1-6

These ostracods were described by Frederick Chapman from the deposits of Mowbray Swamp, North-west Tasmania, and Boneo Swamp, west of Cape Schanck, Victoria, and the types were housed in the National Museum, Melbourne.

The present writer noticed the close resemblance between these two forms and *Limnicythere percivali* Brehm, 1939 (*Zool. Anzeiger,* 127 : 191) from the upper yellow deposits of the Pyramid Valley moa swamp, North Canterbury, New Zealand. After a study of Chapman's type material it was evident that revised descriptions and figures were desirable.

Limnicythere mowbrayensis and *L. sicula* appear to be two distinct species. This can hardly be confirmed with certainty on the basis of existing material, as none of the specimens of *L. mowbrayensis* is a mature adult. It further appears that Chapman figured a male specimen of *L. mowbrayensis,* and a female of *L. sicula,* thus making comparison more difficult. Until Mowbray material has been re-examined for adults of *L. mowbrayensis,* the possibility that the two forms are the same species cannot be definitely ruled out.

Chapman made no mention of types in his descriptions, nor is any specimen separated on the slides. As the writer was unable to definitely identify any specimen with Chapman's figures he concluded that no holotypes existed, and accordingly selected and figured a lectotype for each species.

The writer expresses his appreciation for the ready co-operation of the Director, National Museum of Victoria, in making the types available.

Revised Description of *Limnicythere mowbrayensis* and *L. sicula*

Limnicythere mowbrayensis Chapman. Pl. 1, figs. 1, 2 and 5.
1914. *Mem. nat. Mus. Melbourne,* No. 5, p. 60, pl. 2, figs. 8, a-c.

Carapace minute, subrectangular to subquadrate, somewhat higher at the antero-dorsal angle; moderately inflated with a deep

dorso-median sulcus; left valve overlapping right at anterior and posterior margins; dorsal margin straight, ventral margin arched; anterior margin low and broadly rounded; shell thin, pellucid, delicate; surfaces finely pitted and with four smooth tubercles, the postero-ventral one, faint; hinge straight, simple; radial canals numerous; duplicatures wide; muscle scars in a central vertical group of four; sexual dimorphism marked.

Dimensions of lectotype: L 0·38 mm.; H 0·22 mm.; W 0·17 mm.

Remarks: Distinguished from *L. sicula* by the delicate, finely pitted shell with weak tubercles and by the absence of a prominent horn-like process. Since none of the specimens is a mature adult the specific description may have to be amended when further material has been studied.

Limnicythere sicula Chapman. Pl. I, figs. 3, 4, 6.

1919. *Proc. Roy. Soc. Victoria,* 32 (N.S.) (1): 29, Pl. 4, figs. 10, 11.

Carapace minute, subquadrate to subrectangular, highest at the antero-dorsal angle; strongly inflated with a deep dorso-median sulcus; left valve overlapping right at anterior and posterior margins; dorsal margin straight, ventral margin arched; anterior broadly rounded, posterior margin more compressed; shell thin and translucent, surfaces coarsely pitted and produced as three smooth, rounded, tubercles, prominent in adults; a prominent, recurved, ventro-median, hollow, horn-like process on each valve; hinge simple, straight; radial canals numerous; line of concrescence and inner margin coinciding, duplicatures wide; a central, vertical group of four muscle scars; sexual dimorphism marked.

Dimensions of lectotype: L 0·43 mm.; H 0·28 mm.; W 0·31mm.

Remarks: Distinguished from *L. mowbrayensis* by the prominent, recurved, horn-like processes, the three prominent tubercles and the subquadrate, coarsely pitted shell with blunt antero-dorsal and postero-dorsal angles. The validity of this species will depend on comparison with adults of *L. mowbrayensis*.

Explanation of Plate I

Fig. 1. *Limnicythere mowbrayensis* Chapman, 1914, right valve of lectotype (male); x 110.
Fig. 2. *L. mowbrayensis,* right valve (female); x 110.
Fig. 3. *L. sicula* Chapman, 1919, right valve of lectotype (female); x 110.
Fig. 4. *L. sicula,* left valve (male); x 110.
Fig. 5. *L. mowbrayensis,* dorsal aspect of lectotype; x 110.
Fig. 6. *L. sicula,* dorsal aspect of lectotype; x 110.

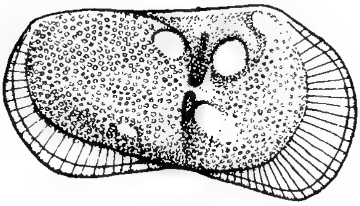

FIG. 1

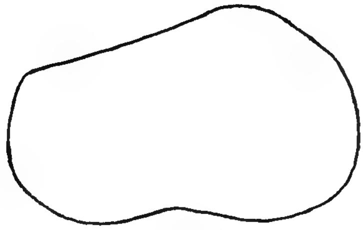

FIG. 2

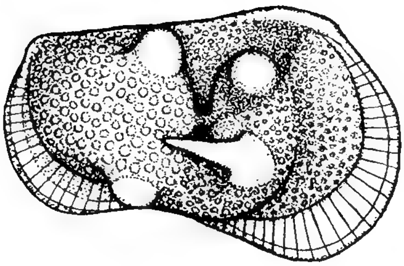

FIG. 3

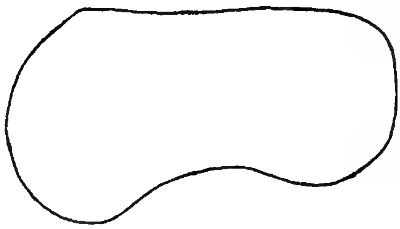

FIG. 4

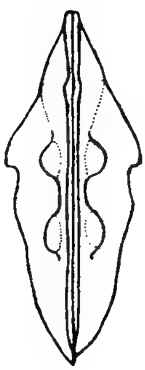

FIG. 5

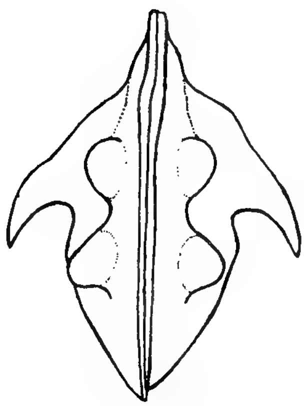

FIG. 6

MEM. NAT. MUS. MELBOURNE, 18, 1953.

CATALOGUE OF QUATERNARY TYPES AND FIGURED SPECIMENS IN THE NATIONAL MUSEUM, MELBOURNE

By Edmund D. Gill, B.A., B.D.
Palaeontologist, National Museum of Victoria

Plate I, figs. 1-9

It is intended that this should be the first part of a check list covering all the palaeontological types and figured specimens in this Museum. The following principles and methods have been observed in housing the types, and compiling this list:

1. Following the established practice of this Museum, registered numbers refer to rock specimens, and not to biological specimens. Thus if there happen to be two types on one slab of rock, they are covered by one registration number. On the other hand, if one biological specimen appears on two counterpart pieces of rock, the two rock specimens carry different numbers. Every piece of a skeleton carries a different number. The numbers are looked upon only as a means of cataloguing and locating certain physical entities quite apart from their nature or content.

2. The registered numbers have been printed in India ink on the specimens. It has been found that labels can come off, or be eaten off by silverfish (*Ctenolepisma longicaudata* Escherich). The number printed in India ink is physically safe and chemically stable.

3. The specimens are marked with a red dot if a first order type, and with a green dot if any other kind of type, or a figured specimen. They are wrapped in cotton wool as a rule, and placed in cardboard boxes, duly labelled. The boxes are kept in lock-up steel cabinets with steel trays, which are comparatively fire-proof, dust-proof, and vermin-proof. The conditions are as even as possible with respect to temperature and water-vapour pressure. The building in which the specimens are housed is of brick, patrolled by attendants during the day, and by firemen during the night. The types are thus housed as safely as can be.

4. The nomenclature of these types is essentially biological. For instance, if an animal on which a species is founded is preserved as a fossil on two counterpart pieces of rock, these are not called syntypes, but a holotype, because only one biological entity is involved (cf. Gill 1949, footnote, p. 67).

L

PROTOZOA

Reg. No.

Bolivina subtenuis Cushman. Slide P 15663

Pleistocene.

Drain on north boundary of Port Fairy, Western Victoria, just east of Princes Highway. Military map reference, Port Fairy sheet 1942, 176,678.

Hypotype.

Collins, A. C. This volume, pl. I, fig. 7.

Bulliminella gracilis Collins. Slide P 15664

Pleistocene.

Same locality as *Bolivina subtenuis.*

Holotype.

Collins, A. C. This volume, pl. I, figs. 8*a*, *b*.

Fabularia lata Collins. Slide P 15667

Pleistocene.

Same locality as *Bolivina subtenuis.*

Holotype.

Collins, A. C. This volume, pl. I, figs. 2*a*, *b*.

Fabularia lata Collins. Slide P 15668

Age and locality as foregoing.

Paratype.

Collins, A. C. This volume, pl. I, figs. 3*a*, *b*.

Fabularia lata Collins. Slide P 15669

Age and locality as foregoing.

Paratype.

Collins, A. C. This volume, pl. I, figs. 4*a*, *b*.

Haddonia cf. *minor* Chapman. Slide P 15663

Pleistocene.

Same locality as *Bolivina subtenuis.*

Figured specimen.

Collins, A. C. This volume, pl. I, fig. 6.

Planispirinella tenuis Collins. Slide P 15664

Pleistocene.

Same locality as *Bolivaina subtenuis.*

Holotype.

Collins, A. C. This volume, pl. I, fig. 5.

Quinqueloculina moyensis Collins. Slide P 15666

Pleistocene.

Inland side of ridge on which Princes Highway runs, between Toolong Road and Glaxo Factory ($1\frac{1}{4}$ miles north of Port Fairy), and on both sides of next ridge inland for some distance, including railway cutting at 185 miles.

Holotype.

Collins, A. C. This volume, pl. I, figs. 1*a*-*c*.

Vagocibicides cf. *maoria* Finlay. Slide P 15663

Pleistocene.

South bank of Moyne River, 1-3 mile E.N.E. of Rosebrook Bridge. Military map reference, Port Fairy sheet 1942, 204,713.

Porifera

Spongilla sp. spicules in opal. P 14630
?Pleistocene.
Tintenbar, Richmond River, New South Wales.
Specimen from which slice cut to make slide P 15630.
Chapman, F., 1922. *Proc. Roy. Soc. Vic.* 34 (2): 167-171, text-figure 2.

Spongilla sp. spicules from opal nodule. Slide P 15630
Age and locality as above.
Figured specimen.
Chapman, F., 1922. *Proc. Roy. Soc. Vic.* 34 (2): 167-171, text-figure 2.

Arthropoda

Candona lutea King. Slide P 14801
Pleistocene.
Mowbray Swamp, N.W. Tasmania.
Two hypotypes.
Chapman, F., 1914. *Mem. Nat. Mus. Melb.* 5, p. 60, pl. 2, figs. 6, 7.

Candonocypris assimilis Sars. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria. (Also called the Tootgarook Swamp. See Keble 1950.)
Hypotype.
Chapman, F., 1919. *Proc. Roy. Soc. Vic.* 32: 28-29, pl. 4, figs. 8-8*a*.

Cypris mytiloides Brady. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Ibid.* p. 27, pl. 3, figs. 5-5*a*.

Cypris sydneia King. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Ibid.* pp. 27-28, pl. 4, figs. 6-6*a*.

Cypris tenuisculpta Chapman. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Holotype.
Chapman, F., 1919. *Ibid.* p. 28, pl. 4, figs. 7-7*b*.
On the type slide, in section 8, are two specimens, viz. (a) Two valves together, and (b) a single valve. In section 7 of the same slide there are three uncleaned specimens, all single valves. It is not clear whether Chapman's figures are all of specimen (a), but they could be, and this is accepted as the holotype.

Cythere lubbockiana Brady. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Ibid.* p. 29, pl. 4, fig. 9.

Limnicythere mowbrayensis Chapman. Slide P 14801
Pleistocene.
Mowbray Swamp, N.W. Tasmania.
Lectoholotype.
Chapman, F., 1914. *Mem. Nat. Mus. Melb.* 5, p. 60, pl. 2, fig. 8.
In an accompanying paper (pp. 155-156, pl. 1, figs. 1-2, 5), Hornibrook has selected the specimen in section 17 of slide P 14801 as lectoholotype.

Limnicythere sicula Chapman. Slide P 14846
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Lectoholotype. In an accompanying paper (pp. 155-156, pl. 1, figs. 3-4, 6), Hornibrook has selected the specimen of this species in section 9 of slide P 14846 as the lectoholotype.

GASTEROPODA

Coxiella confusa Smith. P 14267
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Proc. Roy. Soc. Vic.* 32: 25-26, pl. 3, fig. 3.

Lenameria acutispira (Tryon). P 14265
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Ibid.* p. 26, pl. 3, fig. 4.

LAMELLIBRANCHIATA

Anadara trapezia (Deshayes). P 15674
Holocene.
Victoria Dock excavations, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. Geology of Melbourne, 8vo Melbourne, fig. 7.

Austrocochlea constricta (Lamarck) 1822. P 15673
Holocene.
Victoria Dock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. *Ibid,* fig. 7.

Macoma deltoidalis (Lamarck). P 15676
Holocene.
Victoria Dock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. *Ibid,* fig. 7.

Melliteryx helmsi (Hedley). Slide P 14266
Pleistocene.
Boneo Swamp, Mornington Peninsula, Victoria.
Hypotype.
Chapman, F., 1919. *Proc. Roy. Soc. Vic.* 32: 25, pl. 3, figs. 1-2.

Notospisula parva (Petit). P 15672
Holocene.
Victoria Dock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. The Geology of Melbourne, fig. 7.

Parcanassa jonasi (Dunker). P 15675
Holocene.
Victoria Dock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. *Ibid,* fig. 7.

Pinna inermis Tate. P 13161
Pleistocene.
Ooldea, South Australia.
Hypotype.
Chapman, F., 1920. *Proc. Roy. Soc. Vic.* 32: 229, pl. 16, fig. 2.

Uber conicum (Lamarck). P 15671
Holocene.
VictoriaDock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. The Geology of Melbourne, fig. 7.

Uber plumbea (Lamarck). P 15677
Holocene.
Victoria Dock excavation, Melbourne.
Figured specimen.
Pritchard, G. B., 1910. The Geology of Melbourne, fig. 7.

Reptilia

Emydura cf. *macquariae* Gray. P 13160
?Pleistocene.
Carapook, near Casterton, Western Victoria.
Figured specimen.
Chapman, F., 1919. *Proc. Roy. Soc. Vic.* 32: 11-13, pl. 1, figs. 1-2.

Aves

Dromaius minor Spencer.
Quaternary.
Southern extremity of King Island (Seal Bay and Surprise Bay).
Syntypes. This species was erected by Spencer (1906), then elaborated by Spencer and Kershaw (1910). With the original description there were no figures and no indication of types, nor were types selected by Spencer and Kershaw. The specimens described and figured by Spencer and Kershaw are therefore listed as syntypes, from which, later, lectotypes will no doubt be chosen.
Spencer, B., and Kershaw, J. A., 1910. *Mem. Nat. Mus. Melb.*

3, Pl. 4, fig. 15	P 15060	3, Pl. 5, fig. 3	P 15067
3, Pl. 4, fig. 14	P 15061	3, Pl. 3, fig. 6	P 15068
3, Pl. 4, fig. 20	P 15062	3, Pl. 3, fig. 8	P 15069
3, Pl. 4, fig. 18	P 15063	3, Pl. 3, fig. 5	P 15070
3, Pl. 5, fig. 2	P 15064	3, Pl. 4, fig. 5	P 15071
3, Pl. 5, fig. 4	P 15065	3, Pl. 4, fig. 7	P 15072
3, Pl. 5, fig. 5	P 15066	3, Pl. 4, fig. 8	P 15073

3, Pl. 3, fig. 2	P 15074
3, Pl. 4, fig. 4	P 15075
3, Pl. 4, fig. 3	P 15076
3, Pl. 4, fig. 2	P 15077
3, Pl. 3, fig. 1	P 15078
3, Pl. 3, fig. 3	P 15079
3, Pl. 4, fig. 6	P 15080
3, Pl. 4, fig. 10	P 15081
3, Pl. 4, fig. 11	P 15082
3, Pl. 4, fig. 12	P 15083
3, Pl. 3, fig. 4	P 15084
3, Pl. 3, fig. 11	P 15085
3, Pl. 3, fig. 12	P 15086
3, Pl. 4, fig. 17	P 15087
3, Pl. 2, fig. 2	P 15088
3, Pl. 2, fig. 3	P 15089
3, Pl. 2, fig. 4	P 15090
3, Pl. 2, fig. 5	P 15091
3, Pl. 2, fig. 6	P 15092
3, Pl. 2, fig. 7	P 15093
3, Pl. 7, fig. 3	P 15095
3, Pl. 7, fig. 4	P 15096
3, Pl. 7, fig. 2	P 15097
3, Pl. 6, figs. 2, 3, 5	P 15098
3, Pl. 6, figs. 1, 4, 6, 7 (part)	P 15099
33, Pl. 6, fig. 7 (part) ..	P 15100

Dromaius minor is listed as a full species in the Royal Australasian Ornithologists Union Checklist (1926), and in Mathews (1946), but some think it should have the standing of a sub-species only. Authors also vary on whether the genus should be *Dromaius* or *Dromiceius*.

Mammalia

Arctocephalus williamsi McCoy. P 12110
Pleistocene.
Queenscliff, Victoria.
Syntype (skull).
McCoy, F., 1877. *Prod. Pal. Vic.,* Dec. 5: 7-9, Pl. 41, figs. 1-1*b*, Pl. 42, figs. 1*c*-1*e* (figures reversed).

Arctocephalus williamsi McCoy. P 12111
Pleistocene.
Cape Otway, Victoria.
Syntype (right ramus).
McCoy, F., 1877. *Ibid,* pl. 42, figs. 2-2*a* (figures reversed).

"The Buchan Bone". P 15276
Quaternary.
Buchan Caves, Gippsland, Victoria.
Figured specimen.
Spencer, B., and Walcott, R. H., 1911. *Proc. Roy. Soc. Vic.* 24: 111-114, pl. 38, fig. 2.

Bone fragments allegedly chewed by *Thylacoleo carnifex* P 15287-15317, 15752
Pleistocene.
Pejark Marsh, north of Terang, Victoria.
Figured specimens.
Spencer, B., and Walcott, R. H., 1911. *Ibid,* pp. 92-109, pl. 36, figs. 1-2, 7-8, 10-17, pl. 37, figs. 1-19, pl. 38, fig. 1.
Keble, R. A., 1947. *Mem. Nat. Mus. Melb.,* 15: 58-63, pl. 2, figs. 2-5.

Canis familiaris dingo Blumenbach. P 7443
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Hypotype.
McCoy, F., 1882. *Prod. Pal. Vic.,* Dec. 7: 7-10, pl. 61, figs. 1-1*a* (figures reversed).

Canis familiaris dingo Blumenbach. P 7446
Pleistocene.
Lake Colongulac, north of Camperdown, Victoria.
Hypotype.
McCoy, F., 1882. *Ibid*, pl. 61, figs. 2-2*a* (figures reversed).

Canis familiaris dingo Blumenbach. P 7447
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Hypotype.
McCoy, F., 1882. *Ibid*, pl. 61, figs. 3-3*a* (figures reversed).

Canis familiaris dingo Blumenbach. P 1448
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Hypotype.
McCoy, F., 1882. *Ibid*, pl. 61, fig. 4 (figure reversed).

"*The Colongulac Bone*". P 15275
Pleistocene.
Lake Colongulac, Victoria.
Figured specimen.
Spencer, B., and Walcott, R. H., 1911. *Proc. Roy. Soc. Vic.* 24: 114-118, pl. 38, figs. 3-3*a*.
Keble, R. A., 1947. *Mem. Nat. Mus. Melb.* 15: 58-63, pl. 2, fig. 9.

Dasyurus affinis McCoy. P 7425
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Syntype (left ramus).
This species was erected by a note on the Geological Survey of Victoria Quarter Sheet 7 N.W. Dr. D. E. Thomas, Chief Government Geologist, advises me that the survey was completed in 1860, and records show that the Quarter Sheet was published before June 1862. Unless any new information becomes available, therefore, this species can be dated 1862.

Dasyurus affinis McCoy. P 7426
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Syntype (also a left ramus).
McCoy, F., 1862. See note on P 7425. The two syntypes have not been previously figured, and so photographs are now published (Pl. 1, figs. 1-9).

Dasyurus bowlingi Spencer and Kershaw. P 15101
Quaternary.
Southern extremity, King Island, Bass Strait.
Syntype (skull).
Spencer, B., and Kershaw, J. A., 1910. *Mem. Nat. Mus. Melb.* 3: 29-33, pl. 8, fig. 1.
The age of the King Island fossils has been given as Holocene in the past, but from the same deposit have come the remains of extinct giant marsupials. The author

considers it better to call these fossils quaternary until the age has been worked out.

Dasyurus bowlingi Spencer and Kershaw. P 15102
Same age and locality as P 15101.
Syntype.
Spencer, B., and Walcott, J. A., 1910. *Ibid,* pl. 8, fig. 2.

Dasyurus bowlingi Spencer and Kershaw. P 15111
Same age and locality as P 15101.
Syntype (right ramus).
Spencer, B., and Kershaw, J. A., 1910. *Ibid,* pl. 8, fig. 4.

Dasyurus bowlingi Spencer and Kershaw. P 15112
Age and locality as P 15101.
Syntype (right ramus).
Spencer, B., and Kershaw, J. A., 1910. *Ibid,* pl. 8, fig. 5.

Diprotodon longiceps McCoy. P 12109
Pleistocene.
Well excavation, Colac, Victoria.
Holotype.
McCoy, F., 1876. *Prod. Pal. Vic.,* Dec. 4: 7-11, pls. 31-32, figs. 1-1*d,* pl. 33, fig. 1 (figures reversed), text fig. 1.

Diprotodon optatum Owen. P 15283
Pleistocene.
Pejark Marsh, north of Terang, Victoria.
Hypotype (lower incisor).
Keble, R. A., 1947. *Mem. Nat. Mus. Melb.* 15: 49, pl. 2, fig. 10.

Diprotodon optatum Owen. P 15284
Same age and locality as P 15283.
Hypotype (portion of diastema).
Keble, R. A., 1947. *Ibid,* pl. 2, fig. 11.

Homo sapiens (Australian aborigine) P 15437-15528
Mid-Holocene arid period.
Loess dune, N.E. of "Chocolyn" homestead, east side of Lake Colongulac, Victoria.
Figured specimen. "The Colongulac Skeleton".
Gill, E. D., 1951. *Aust. Journ. Sci.* 14 (3): 69-73.
——, 1953. This Memoir, pp. 25-92, pl. IV, fig. 7.

Macropus titan Owen. P 1891
Pleistocene.
Colac, Victoria.
Hypotype (mandible).
McCoy, F., 1879. *Prod. Pal. Vic.,* Dec. 6: 5-7, pl. 51, figs. 1-1*a* (figures reversed).

Macropus titan Owen. P 12112
Pleistocene.
Lake Timboon (= Lake Colongulac), Western Victoria.
McCoy, F., 1879. *Ibid,* pl. 51, fig. 2 (figure reversed).

Macropus titan Owen. P 12113
Age and locality as P 12112.
Hypotype.
McCoy, F., 1879. *Ibid,* pl. 51, fig. 3 (figure reversed).

Macropus titan Owen. P 12114
Age and locality as P 12112.
Hypotype.
McCoy, F., 1879. *Ibid,* pl. 51, fig. 4 (figure reversed).

Macropus titan Owen. P 12115
Age and locality as P 12112.
Hypotype.
McCoy, F., 1879. *Ibid,* pl. 51, fig. 5 (figure reversed).

Procoptodon goliah (Owen). P 1908
Age and locality as P 12112.
Hypotype.
McCoy, F., 1879. *Ibid,* pp. 9-11, pl. 53, figs. 1-1*b* (figures reversed).

Procoptodon goliah (Owen). P 1910
Age and locality as P 12112.
Hypotype.
McCoy, F., 1879. *Ibid,* pl. 52, figs. 1-1*f,* (figures reversed, and 1*f* erroneously labelled 1*b*).

Sarcophilus harrisii (Boitard). P 1857
Quaternary.
Cave, five miles S.E. of Gisborne, Victoria.
Hypotype.
McCoy, F., 1882. *Prod. Pal. Vic.,* Dec. 7: 11-13, pl. 61, figs. 5-5*a* (figures reversed).

Sarcophilus harrisii (Boitard). P 7432
Pleistocene.
Queenscliff, Victoria.
Hypotype.
McCoy, F., 1882. *Ibid,* pl. 62, figs. 1-1*b,* pl. 63, figs. 1-1*d.*

Thylacoleo carnifex Owen. P 1902
Pleistocene.
Lake Colongulac, north of Camperdown, Victoria.
McCoy, F., 1876. *Ibid,* Dec. 3: 7-12, pl. 21, figs. 1-1*b* (figures reversed). Text figures 1-2.

Thylacoleo carnifex Owen. P 1903
Age and locality as P 1902.
Hypotype.
McCoy, F., 1876. *Ibid,* pl. 21, figs. 2-2*a* (figures reversed).

Thylacoleo carnifex Owen. P 13022
Pleistocene.
Buchan Caves, Gippsland, Victoria.
Hypotype.
Spencer, B., and Walcott, R. H., 1911. *Proc. Roy. Soc. Vic.* 24: 107, pl. 39, figs. 2-2*a.*

Thylacoleo carnifex Owen. P 15363
Age and locality as P 13022.
Hypotype.
Spencer, B., and Walcott, R. H., 1911. *Ibid,* pl. 39, figs. 1-1*a.*

Vombatus pliocenus (McCoy). P 7441
Quaternary.
Lake Bullenmerri, Victoria.
Syntype.
McCoy, F., 1874. *Prod. Pal. Vic.*, Dec. 1: 21-22, pl. 5, figs. 2-2*b* (figures reversed).

Vombatus pliocenus (McCoy). P 7442
Age and locality as P 7441.
Syntype.
McCoy, F., 1874. *Ibid*, pl. 5, figs. 1-1*a* (figures reversed).

Vombatus ursinus (Shaw). P 15103
Quaternary.
Southern extremity, King Island, Bass Strait.
Hypotype (femur).
Spencer, B., and Kershaw, J. A., 1910. *Mem. Nat. Mus. Melb.* 3, 37-63, pl. 11, fig. 9.

Vombatus ursinus (Shaw). P 15104
Age and locality as P 15103.
Hypotype (femur).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 11, fig. 11.

Vombatus ursinus (Shaw). P 15105
Age and locality as P 15103.
Hypotype (humerus).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 11, fig. 13.

Vombatus ursinus (Shaw). P 15106
Age and locality as P 15103.
Hypotype (skull).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 9, fig. 1.

Vombatus ursinus (Shaw). P 15107
Age and locality as P 15103.
Hypotype (skull).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 9, fig. 3.

Vombatus ursinus (Shaw). P 15108
Age and locality as P 15103.
Hypotype (skull).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 9, fig. 5.

Vombatus ursinus (Shaw). P 15109
Age and locality as P 15103.
Hypotype (lower jaw).
Spencer, B., and Kershaw, J. A., 1910. *Ibid*, pl. 11, fig. 3.

Vombatus ursinus (Shaw). P 15110
Age and locality as P 15103.
Hypotype (lower jaw).
Spencer, B., and Kershaw, 1910. *Ibid*, pl. 11, fig. 4.

Vombatus sp. P 12281
Quaternary.
Lake Bullenmerri, Victoria.
Figured specimen (sacrum and left os innominatum).
McCoy, F., 1882. *Prod. Pal. Vic.*, Dec. 7: 30, pl. 70 and text figure.

Plantae

Cladophora richmondensis Chapman. Slide P 15631
?Pleistocene.
Tinternbar, Richmond River, N.S.W.
Holotype.
Chapman, F., 1922. *Proc. Roy. Soc. Vic.* 34: 167-171, text figure 1.

Casuarina cf. *stricta* Aiton P 12714
Quaternary.
Yandoit Hill, Vic.
Figured specimen.
Chapman, F., 1914. *Vic. Nat.* 31: 89-91, pl. 3.

?Casuarina in position of growth in clayey sand, and caught up in the base of an overlying basalt flow. P 14895
Pleistocene.
Excavation for entry to bins of basalt quarry, north side of Gordon Street, Maribyrnong, Victoria.
Figured specimen.
Gill, E. D., and Baker, A. A., 1950. *Vic. Nat.* 67: 123-129, fig. 2.

?Casuarina. P 14896
Age and locality as P 14895.
Counterpart of figured specimen P 14895.

Cribbate Pollen Grain. Slide P 15653
Holocene.
Mottled brownish clay resting on marine shellbed, right bank of Moyne River, 0·6 mile slightly east of north of Rosebrook Bridge, Princes Highway, Western Victoria.
Figured specimen.
Cookson, Isabel, 1953. This Memoir, p. 122, pl. I, fig. 19.

?Eucalyptus sp. Cast of a tree in basalt. P 15568
Pleistocene.
J. White's quarry, Footscray, Victoria.
Figured specimen.
Walcott, R. H., 1899. *Proc. Roy. Soc. Vic.* 12: 141-144, pl. 13.
Also figured are two parts of the mould, which are numbers P 15569 and 15570. These specimens were exhibited at the Intercolonial Exhibition held in Melbourne in 1866, so must have been collected prior to that.

Hystrichosphaera furcata (Ehrenberg) O. Wetzeal. P 15652
Holocene.
Same locality as the cribbate pollen grain P 15653.
Hypotype.
Cookson, Isabel, 1953. This Memoir, p. 113, pl. I, fig. 17.

Plant remains in a concretionary nodule. P 15632
Quaternary.
Old bed of Yarra River, South Melbourne. From a depth of sixteen feet in Power Street, near Grant Street.
Figured specimen.
Chapman, F., 1906. *Geol. Mag.* 5 (3): 553-556, figs. 1-2.

Thick walled Hair. Slide P 15644

Quaternary.

South Ecklin, twelve miles from Terang, Western Victoria.

Figured specimen (from peat).

Cookson, Isabel, 1953. This Memoir, pp. 107-122, pl. I, fig. 18.

References

Gill, E. D., 1949. Palaeozoology and taxonomy of some Australian homalonotid trilobites. *Proc. Roy. Soc. Vic.* 61: 61-73.

Keble, R. A., 1950. The Mornington Peninsula. *Mem. Geol. Surv. Vic.* 17. See text figure 59, and map.

Mathews, G. M., 1910. The Birds of Australia. Vol. 1, pt. 1. 4to. London.

Spencer, B., 1906. The King Island Emu. *Vic. Nat.* 23: 139-140.

Spencer, B., and Kershaw, J. A., 1910. A collection of sub-fossil bird and marsupial remains from King Island, Bass Strait. *Mem. Nat. Mus. Melb.* 3: 1-36.

Explanation of Plate

All the figures are of the two syntype specimens of *Dasyurus affinis* McCoy, not previously figured.

Figures 1-3 are of specimen P 7425 and are natural size.

Figures 5-6 are of specimen P 7426 and are natural size.

Figures 4, 8, 9 are parts of figures 5-6 enlarged twice to show better details of the teeth.

The photographs were taken by Mr. L. A. Baillôt of the Melbourne Technical College.


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RECORD OF A SOUTH AFRICAN MOLLUSC FROM AUSTRALIA (*Haliotis sanguinea* Hanley)

J. Hope Macpherson, B.Sc.,
Conchologist, National Museum of Victoria

Plate I

In February 1952 a number of Molluscs collected alive at Cowaramup Bay, South of Yallingup, Western Australia, was forwarded to the National Museum by Mrs. J. A. Grigg, an experienced collector, for identification. Amongst them were three specimens of Haliotis which are quite distinct from any previously recorded from Australia. Mrs. Grigg later gave one specimen to the Museum, F 12987, and it is figured here.

The shell obviously was close to Hanley's *Haliotis sanguinea* for which the locality is not given in the original description. Comparison with examples of that species in the Museum collection was then made. These are five in number, four from the Cape of Good Hope (two from the Hugh Cuming Collection) and one from Mauritius. Reeve and later authors confine the species to the first locality.

The Museum specimens form a very uniform series, and with them the Western Australian shells agree perfectly in form, sculpture and colour. There is, therefore, no justification, other than geographical, for separating them, even subspecifically from Hanley's species and they are here recorded as—

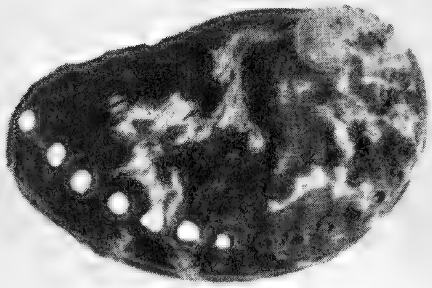
Haliotis sanguinea Hanley

Haliotis sanguinea Hanley, Young Conchologist's Book of Species, p. 60, frontispiece fig. 5, 1840
Reeve, Conch. Icon., III, fig. 17, 1846.
Sowerby, This Conch., V, sp. 27; fig. 93, 4; 1883.
Weinkauff, Conchyl. Cab., Bd. VI, t. 16, f. 3, 4, 1840.

Haliotis ficiformis Menke, Zeitschr. f. Mal., 1845, p. 7.
Philippi, Abbild Conch., II, p. 70, t. 4, f. 3, 1847.

Localities—Cape of Good Hope, Mauritius and Western Australia.

Mrs. Grigg attached the following field notes to the specimens —"Living amongst weed on hard rock bottom, below low water mark, usually under limestone rocks. Largest taken 61 mm., smallest 46 mm. long. Five specimens in all."



Haliotis sanguinea Hanley. Cowaramup Bay, Western Australia.
(natural size)

S 1005–

Brown, Prior, Anderson Pty. Ltd., 430 Little Bourke Street, Melbourne